LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

ADMINISTRATIVE RECORD

VOLUME 4 of 10

1997

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Prepared for:

Department of the Army
Longhorn Army Ammunition Plant
Marshall, Texas 75671

1997

VOLUME 4 of 10

1997

A. Title: Memorandum, Subject: Draft Final Group 5 Site Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas
Group(s): 5
Site(s): 52, 63
Location: Longhorn Army Ammunition Plant
Agency: USACE, Tulsa, CESWT-PP-Me
Author: Yolane Hartsfield, Project Manager
Recipient: Mr. Jim Martell, CESWT-EC-GS
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B. Title: Letter, Subject: Final Remedial Investigation Report Group 1 Sites (Sites 1, 11, 27, and XX) and Volume 2 Baseline Risk at the Longhorn Army Ammunition Plant, Karnack, Texas
Group(s): 1
Site(s): 1,11,27, and XX
Location: Longhorn Army Ammunition Plant
Agency: USACE, Tulsa District
Author: Yolane Hartsfield
Recipient: Mr. David Tolbert, SIOLH-OR
Date: 30 April l997
Bate Stamp: 19754 - 20205

019753

CESWT-PP-ME

18 March 1997

MEMORANDUM FOR CESWT-EC-GS (MR. JIM MARTELL)

SUBJECT: Draft Final Group 5 Site Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas

1. Pursuant to a telephone conversation this date with Mr. Chris Villareal, USEPA Superfund Division, Region 6, Dallas, Texas, this memorandum documents that the EPA has no review comments on the above Draft Final document.

2. An action item from the Technical Review Committee Meeting held 11 March 1997 is to direct Sverdrup to include in the conclusions and recommendation section(s), where appropriate, language stating "no further action" with respect to Sites 52 and 63.

3. The point of contact is Ms. Yolane Hartsfield, ext. 7530.

Yolane Hartsfield

Yolane Hartsfield
Project Manager

CF:
LHAAP-SIOLH-OR (Mr. David Tolbert)

DEPARTMENT OF THE ARMY
TULSA DISTRICT, CORPS OF ENGINEERS
POST OFFICE BOX 61
TULSA, OKLAHOMA 74121-0061

019754

REPLY TO
ATTENTION OF:

CESWT-PP-ME (200-1c)

30 April 1997

MEMORANDUM FOR Commander, Longhorn/Louisiana Army Ammunition Plants, ATTN: SIOLH-OR (Mr. David Tolbert), Post Office Box 658, Doyline, LA 71023

SUBJECT: Final Remedial Investigation Report Group 1 Sites (Sites 1, 11, 27, and XX) and Volume 2 Baseline Risk at the Longhorn Army Ammunition Plant, Karnack, Texas

1. Please find enclosed two copies of the subject document for your review and comments. Please submit comments by 30 May 1997. Comments submitted before the due date will be greatly appreciated.

2. If you have any questions, please contact Ms. Yolane Hartsfield at 918-669-7530.

FOR THE COMMANDER:

Yolane Hartsfield
for BURL D. RAGLAND
Lead Project Manager
Army Team

Encls

FINAL
REMEDIAL INVESTIGATION REPORT
GROUP 1 SITES

VOLUME II

BASELINE RISK ASSESSMENTS
GROUP I SITES (SITES 1, 11, 27, AND XX)
LONGHORN ARMY AMMUNITION PLANT, KARNACK, TX

Prepared For:

Longhorn Army Ammunition Plant
Karnack, Texas

Prepared By:

U.S. Army Corps of Engineers
Tulsa District

JULY 1997

EXECUTIVE SUMMARY

Baseline risk assessments were prepared to support site management decisions for Group 1 Sites (Sites 1, 11, 27, and XX), Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. These assessments represent estimates of potential human health and ecological impacts resulting from contaminant release at these sites in the absence of remediation. Methodology used in these assessments was that prescribed by the U.S. Environmental Protection Agency.

Human health evaluations for all Group 1 sites were conducted for both current recreational and future industrial land uses. A variety of potential pathways for human exposure were evaluated and are documented in this report. While carcinogenic and non-cancer risk estimates included values for both reasonable maximum exposure (RME) and central tendency exposure (CTE), RME values were most conservative and are provided in this summary. Risk estimates were evaluated based on an acceptable carcinogenic risk range of 10^{-4} to 10^{-6} and an acceptable non-cancer hazard index of unity (1.0). All estimation techniques, assumptions, methodology, and degrees of uncertainty associated with risk quantification are provided in this document. As a rule, conservative assumptions were used throughout the risk assessment process to help mitigate recognized uncertainties.

Ecological evaluations for all Group 1 sites were conducted as conservative "screening-level" assessments as described in current ecological risk assessment guidance (USEPA 1994). The intent of this approach was not to quantify actual ecological risks, but rather to identify, using highly conservative methodology, sites requiring further, more detailed ecological evaluation. As documented in each site-specific assessment, impacts were limited to exposure of terrestrial organisms to chemicals present in site soils. Accordingly, screening-level exposure estimates were developed for both a surrogate small mammal and a bird species exposed to site contaminants via ingestion of soil and soil fauna. For small mammal exposure, the least shrew (Cryptotis parva) was used as a conservative model species. Avian exposure was conservatively modeled using estimated intake for the American woodcock (Scalopax minor). Site-specific

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screening-level hazard indices were calculated for each species with values exceeding 1.0 resulting in further evaluation of chemicals driving risk estimates. While not originally used in selection of chemicals of concern, this evaluation frequently involved consideration of background data for metals. Detailed justification for this ecological approach as well as all methods, assumptions, and parameter values are provided in this document.

Chemicals of potential concern (COPC) in site soils and ditch sediments at LHAAP Site 1 (Inert Burning Grounds) included several volatile organic compounds (VOCs), a variety of polycyclic aromatic hydrocarbons (PAHs), and metals. Chemicals of concern in groundwater included several volatile organics and metals. All organics in both media were detected at low frequencies and concentrations. For the human health evaluation, conservative carcinogenic risk estimates of 1E-6 and 7E-6 were obtained for current recreational and future industrial land uses, respectively. Non-cancer hazard indices were very low at 4E-2 (current land use) and 4E-1 (future land use). Accordingly, unacceptable risks to human health were not identified for LHAAP Site 1.

Screening-level risk calculations for ecological effects at Site 1 indicated that further interpretation of results for antimony, chromium, lead, and nickel was warranted. Screening risk estimates for organics present in site soils were extremely low and indicative of little or no ecological risk. Further evaluation of metals data at the site revealed that all four metals are present at concentrations approximating background levels for LHAAP. This analysis failed to support evidence of a chemical release of metals at the site, served to illustrate the conservative nature of methodology used in this assessment, and indicated that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. Accordingly, unacceptable ecological risks were not identified for LHAAP Site 1 and further ecological evaluation was not conducted.

For Site 11 (Suspected TNT Burial Site), COPC in site soils included metals and methylene chloride (detected at low levels in two soil borings). While present at background levels, metals were evaluated as chemicals of concern in groundwater as a measure of overall cumulative site risk for future land uses. No explosives were detected at the site. For the human health assessment, conservative carcinogenic risk estimates of 3E-7 and 2E-6 were obtained for current and future land uses, respectively. Hazard indices of 3E-2 (current land use) and 3E-1 (future land use) were likewise low at the site. As such, no unacceptable risks to human health were identified for LHAAP Site 11.

Ecological evaluations based on the least shrew and woodcock models for Site 11 resulted in identification of chromium, lead, and nickel as the only COPC requiring further evaluation relative to ecological impacts at the site. A comparison of site data and background levels for the facility revealed that these metals exist at the site at naturally-occurring levels. Accordingly, little or no ecological concerns were identified by this assessment for LHAAP Site 11.

The most significant finding at LHAAP Site 27 (South Test Area) was the presence of nickel in groundwater at detected concentrations ranging from 0.12 to 0.37 mg/l. These concentrations all exceeded both groundwater background levels for the facility and the drinking water maximum contaminant level for nickel (0.1 mg/l). All other metals in groundwater as well as site soils were reported at background concentrations, and no organics were detected in any medium at the site. For human health evaluation, carcinogenic risk estimates were well within the acceptable risk range at 1E-7 (current recreational land use) and 3E-5 (future industrial land use). In a similar manner, conservative non-cancer hazard indices were below unity at 1E-2 and 6E-1 for current and future land uses, respectively. Despite elevated concentrations of nickel in groundwater, exposure to this metal via groundwater ingestion was a minor contributor to overall noncarcinogenic risk (hazard quotient of 0.13). Based on these results, no unacceptable risks to human health were identified for LHAAP Site 27.

Screening-level ecological risks calculated for Site 27 were driven by metals (barium, chromium, nickel, and lead) present at naturally-occurring concentrations for the facility. These findings fail to support evidence of a chemical release of these metals at the site, illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, little or no ecological concerns were identified for Site 27.

Evaluated chemicals of concern for LHAAP Site XX (Ground Signal Test Area) were limited to metals present at background concentrations in both site soils and groundwater. Based on these findings, evidence of a chemical release at the site is questionable. However, for the sake of conservatism, risk evaluations for both human health and ecological effects were completed. For human health evaluation, conservative carcinogenic risk estimates of 3E-7 and 2E-6 were obtained for current recreational and future industrial land uses, respectively. Hazard indices were well below the critical value of 1.0 at 2E-2 (current land use) and 1E-1 (future industrial land use). Based on these results, no unacceptable risks to human health were identified for LHAAP Site XX.

In a manner similar to all other Group 1 sites, screening-level ecological risks for Site XX were driven solely by metals present at background concentrations. For Site XX, these metals were limited to chromium and nickel. Based on these conservative analyses, no ecological concerns were identified for the site.

In summary, primary objectives of baseline risk assessments detailed in this report were to provide estimates of risk to both human health and ecological (non-human) receptors at LHAAP Group 1 sites in the absence of site remediation. Based on assumptions, approaches, methods, and uncertainties presented in this document, unacceptable human health and/or ecological risks were not identified for these sites. As such, these assessments fail to support the need for remediation at any LHAAP Group 1 site.

HUMAN HEALTH EVALUATION ADDENDA

Following a review of initial data collected as a part of remedial investigation activities and human health risk characterization based on these results, limited additional surface soil sampling was conducted at all four Group 1 sites. This sampling was initiated to support additional human health risk characterization for limited areas at these sites which were identified during review of original risk assessment results. Site-specific objectives for these additional evaluations varied from verification of the suitability of original data for risk evaluation to actual risk characterization for potential "hot spots" of limited area at the sites. Results of additional evaluations are presented in this document as an addendum immediately following the original human health evaluation for each Group 1 site. These results are in no way meant to replace or supersede original human health risk characterizations, but are provided as supplemental information for comprehensive risk evaluation at the sites.

Detailed methods, assumptions, and conclusions for additional evaluations for each Group 1 site are presented in this document. In summary, unacceptable risk to human receptors under current and future land use scenarios was not identified for any of the four sites. As such, these addenda substantiate conclusions of the original assessment and fail to support the need for site remediation for protection of human health at any Group 1 site.

LIST OF ACRONYMS

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ABS	Adsorption fraction
AF	Adherence Factor
AMCCOM	Army Armament, Munitions, and Chemical Command
AT	Averaging Time
BAF	Bioaccumulation Factor
BW	Body Weights
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF	Conversion Factor
COPC	Chemicals of Potential Concern
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
Cs	Concentration in soil
CTE	Central Tendency Exposure
Cw	Concentration in water
DAD	Dermally Absorbed Dose
ED	Exposure Duration
EF	Exposure Frequency
EIR	Earthworm Ingestion Rate
ET	Event Time
EV	Event Frequency
FI	Fraction Ingested
HSDB	Hazardous Substances Data Base
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HSDB	Hazardous Substances Data Base
IR	Intake Rate
IRIS	Integrated Risk Information System
IEUBK	Integrated Exposure Uptake and Biokenetic
Kg	kilogram
LHAAP	Longhorn Army Ammunition Plant
LOAEL	Lowest-observed-adverse-effects-level
m^3	cubic meter
MCL	Maximum Contaminant Level
mg	milligram
NOAEL	No-observed-adverse-effect-level
NPL	National Priorities List
PAH	Polynuclear Aromatic Hydrocarbons
PC	Permeability Constant
PEF	Particulate Emission Factor
ppb	parts per billion
ppm	parts per million

LIST OF ACRONYMS (Continued)

QA/QC	Quality assurance/quality control
RAGS/HHEM	Risk Assessment Guidance for Superfund/Human Health Evaluation Manual
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RTECs	Registry of Toxic Effects of Chemical Substances
RTVs	Reference Toxicity Values
SA	Surface Area
SCSR	Site Characterization Summary Report
SF	Slope Factor
SIR	Soil Ingestion Rate
SMDP	Scientific Management Decision Point
SQL	Sample Quantitation Limit
SVOCs	Semi-Volatile Organic Compounds
TAL	Target Analyte List
TEF	Toxicity Equivalency Factor
TNRCC	Texas Natural Resources Conservation Commission
TNT	Trinitrotoluene
UCL	Upper Comfidence Limit
ug	microgram
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VF	Volatilization Factor
VOCs	Volatile organic compounds

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BASELINE RISK ASSESSMENTS
GROUP 1 SITES (SITES 1, 11, 27, AND XX)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TX

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CHAPTER 1
INTRODUCTION AND GENERAL METHODOLOGY

1.1 INTRODUCTION

1.1.1 General Overview. Baseline risk assessments were prepared to support site management decisions for Group 1 Sites (Sites 1, 11, 27, and XX), Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. These assessments represent an estimate of potential human health and ecological impacts resulting from contaminant release from these sites in the absence of remediation. Results of a risk assessment help support the decision-making process at chemical release sites by: (1) helping to determine whether additional response action is necessary at a site; (2) aiding in modification of preliminary remediation goals; (3) helping to support selection of the "no action" alternative (where appropriate); and (4) documenting the magnitude of risk to human health and the environment at a site and delineating primary causes of risk (USEPA 1989). Objectives of risk assessments for LHAAP Group 1 sites were to use environmental data collected at each site to provide project managers and decision makers with information necessary to support sound site decisions.

Basic methodology used throughout human health assessments was that prescribed by the U.S. Environmental Protection Agency (USEPA) in Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A) (USEPA 1989), hereafter referenced as RAGS/HHEM. Additional guidance was obtained from the Draft Supplemental Region VI Risk Assessment Guidance, dated April 14, 1992. For ecological evaluations, primary guidance documents included Framework for Ecological Risk Assessments (USEPA 1992a) as well as the

Review Draft Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA 1994). While the latter has yet to be formally adopted by the USEPA, it is anticipated that it will soon serve as the primary protocol for ecological risk assessments. In addition to these primary documents, numerous companion guidance documents, supplemental directives, interim reports, and other sources of information were used and are cited throughout this report.

1.1.2 References to Site-Related Documents. These baseline risk assessments are being prepared as part of the remedial investigation (RI) report for LHAAP Group 1 sites (Volume I). Accordingly, primary information regarding environmental investigation activities that form the basis for risk assessments for these sites was obtained from the RI report and is referenced in this volume. Reference is also made to the Group 1 Site Characterization Summary Report (hereafter referenced as the Group 1 SCSR) prepared by Sverdrup Environmental, Inc., and submitted to the U.S. Army Corps of Engineers (USACE) in October 1995. To prevent redundancy of information concerning environmental data, boring logs, hydrogeology, monitoring well diagrams, geotechnical data, and other site information in final site documents, frequent reference is made to the Group 1 SCSR and RI report.

1.1.3 Report Organization. Site-specific risk assessments for LHAAP Sites 1, 11, 27, and XX are presented in Chapters 2 through 5 of this document, respectively. Human health baseline risk assessments for each site are followed by an addendum to the human health evaluation and the ecological evaluation. As much of the general methodology used in these risk assessments is common to all sites, these methods are detailed in later sections of this chapter to prevent repetitive presentation of methods common to each site-specific risk assessment.

1.2 FACILITY DESCRIPTION

1.2.1 Longhorn Army Ammunition Plant. Longhorn Army Ammunition Plant is located in Harrison County, Texas, approximately 14 miles northeast of Marshall, Texas, and 40 miles west of Shreveport, Louisiana (Figure 1-1). The plant was established in 1945 for production of flake 2,4,6-trinitrotoluene (TNT). The 8,483-acre facility is currently a Government-owned, contractor-operated (Longhorn Division of Thiokol Corporation) facility under the jurisdiction of the U.S. Army Armament, Munitions, and Chemical Command (AMCCOM). Recent activities at LHAAP have included loading, assembling, and packing of pyrotechnic, illuminating, and signal ammunition and solid propellent rocket motors. The facility is bounded by the non-incorporated community of Karnack, Texas, to the west; the small incorporated city of Uncertain, Texas, to the north; the western shore of Caddo Lake to the east; and relatively undeveloped land to the south.

Longhorn Army Ammunition Plant was placed on the National Priorities List (NPL) on August 30, 1990. As a result, environmental remedial activities at a number of sites are currently being conducted under a Federal Facility Agreement among LHAAP, USEPA Region VI, and the Texas Natural Resources Conservation Commission (TNRCC).

1.2.2 Local Area Description. The area surrounding LHAAP is generally known as the Pineywoods of east Texas. The area experiences average annual rainfall of 46 inches, with the most rainfall occurring December through May. All surface water from the installation drains northeastwardly into Caddo Lake via four major drainage systems. Caddo Lake, an important resource to the area, forms portions of the eastern boundary of LHAAP and is divided by the Texas-Louisiana State line (Figure 1-1). The lake is a shallow, eutrophic, natural water body which serves as an important site for a variety of recreational activities, supports a wide diversity of aquatic life, and is also a public water supply source for Marshall, Texas, and Shreveport, Louisiana.

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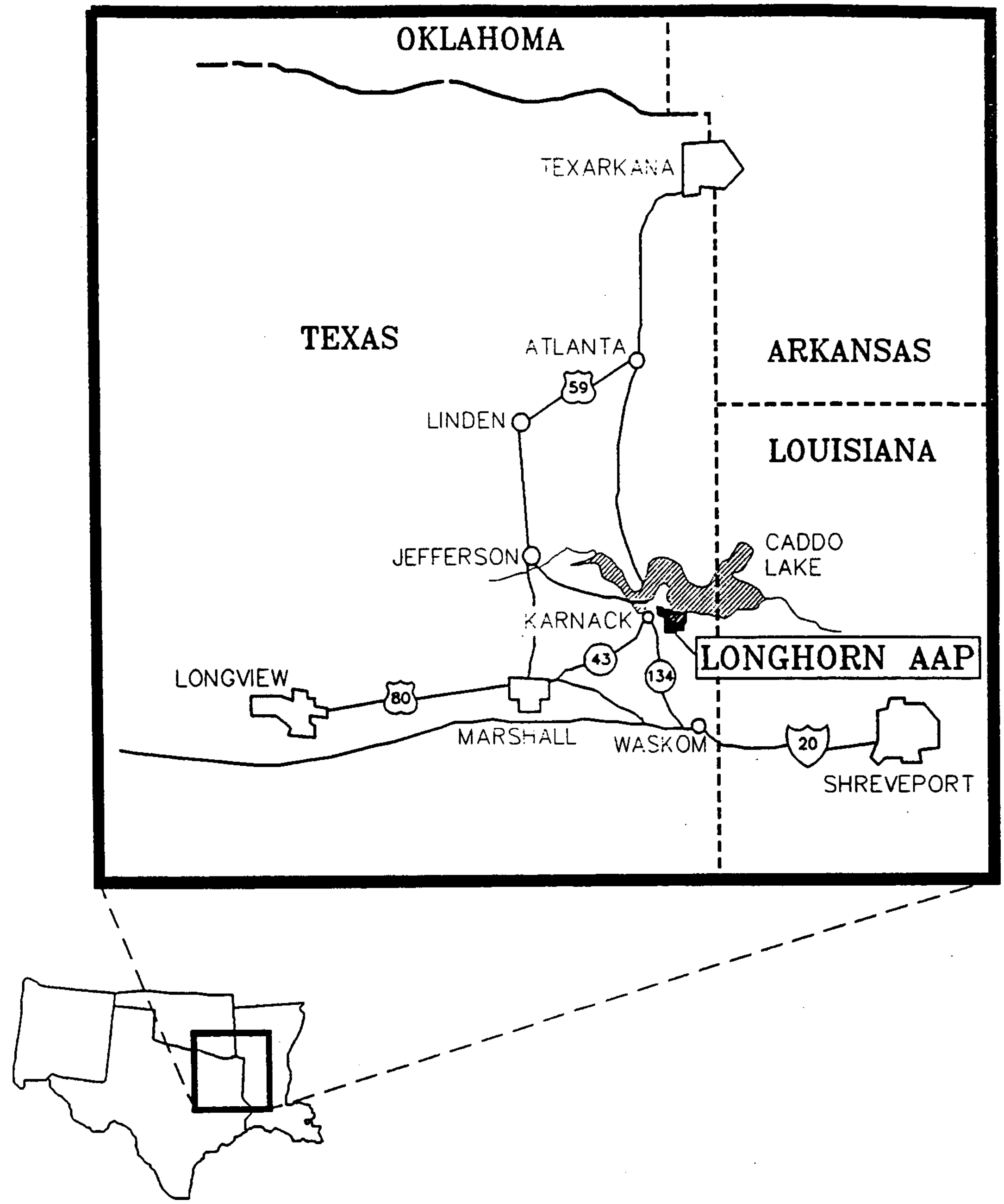


CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

SITE VICINITY MAP

Sverdrup Environmental

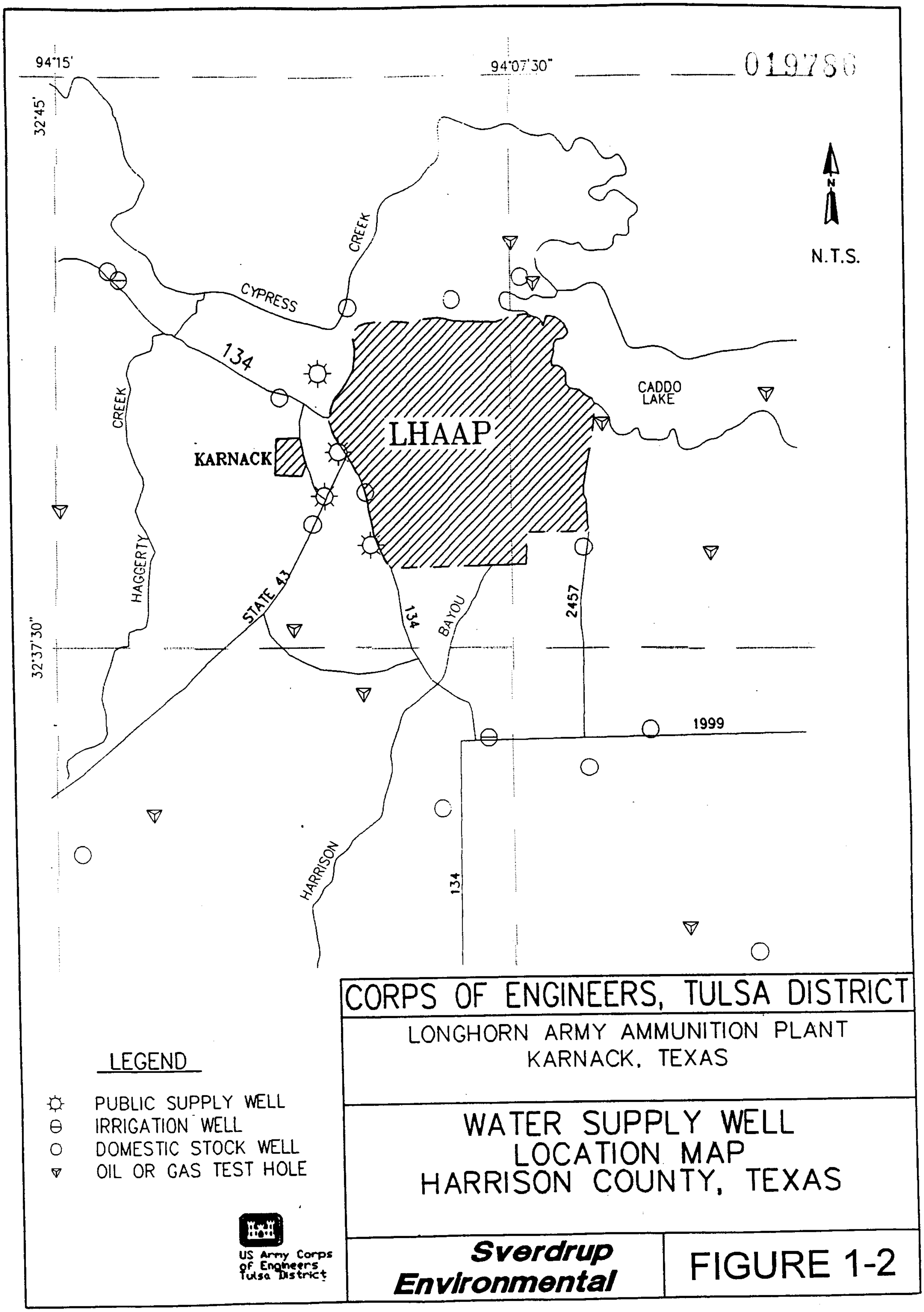
FIGURE 1-1

Detailed descriptions of regional geology and hydrogeology in the vicinity of LHAAP are provided in the Group 1 SCSR. In summary, the facility is situated on an outcrop of the Wilcox Group, which crops out over a large part of the eastern half of Harrison County. The Wilcox consists mostly of fine- to medium-grained sands interbedded with a considerable amount of silt and clay, and occasional seams of lignite. The Wilcox is approximately 120 to 300 feet thick beneath the installation and is underlain conformably by the predominantly calcareous clay of the Midway Group.

The Wilcox has been identified as the basal unit of the regional Cypress aquifer, also known as the Carrizo-Wilcox aquifer. This aquifer is comprised of several units, all believed to be hydraulically connected. The Wilcox yields small (< 50 gallons per minute) to moderate (50 to 500 gallons per minute) quantities of fresh water to wells throughout Harrison County. Groundwater at LHAAP generally occurs under unconfined conditions and can be encountered from within 1 to 30 feet or more below ground surface. Perched and locally confined conditions frequently occur within the Wilcox due to highly variable and complex stratigraphy. Regional groundwater flow is to the east-northeast toward Caddo Lake.

There are no existing water supply wells on LHAAP. Water supply needs of LHAAP are served by an installation water treatment plant that receives water from Big Cypress Bayou. The water treatment plant is located approximately 1,800 feet west of the northwest boundary of the installation. Public water supply wells in use near LHAAP are limited to one located northwest of the facility, in and owned by the Caddo Lake State Park, and one southeast of Karnack. Two standby public wells are likewise located near Karnack. All other wells in the vicinity of LHAAP are used for stock and domestic purposes (Figure 1-2).

1.2.3 <u>Group 1 Sites</u>. For purposes of remedial activities, sites under investigation at LHAAP have been combined into collective groups. General locations of Group 1 sites (Sites 1, 11, 27, and XX) are shown in Figure 1-3. Details of site histories, site descriptions, suspected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STATE 43
134
BAYOU
2457
1999
HARRISON
134
LEGEND
PUBLIC SUPPLY WELL
IRRIGATION WELL
DOMESTIC STOCK WELL
OIL OR GAS TEST HOLE
US Army Corps of Engineers Tulsa District
CORPS OF ENGINEERS, TULSA DISTRICT
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS
WATER SUPPLY WELL
LOCATION MAP
HARRISON COUNTY, TEXAS
Sverdrup Environmental
FIGURE 1-2

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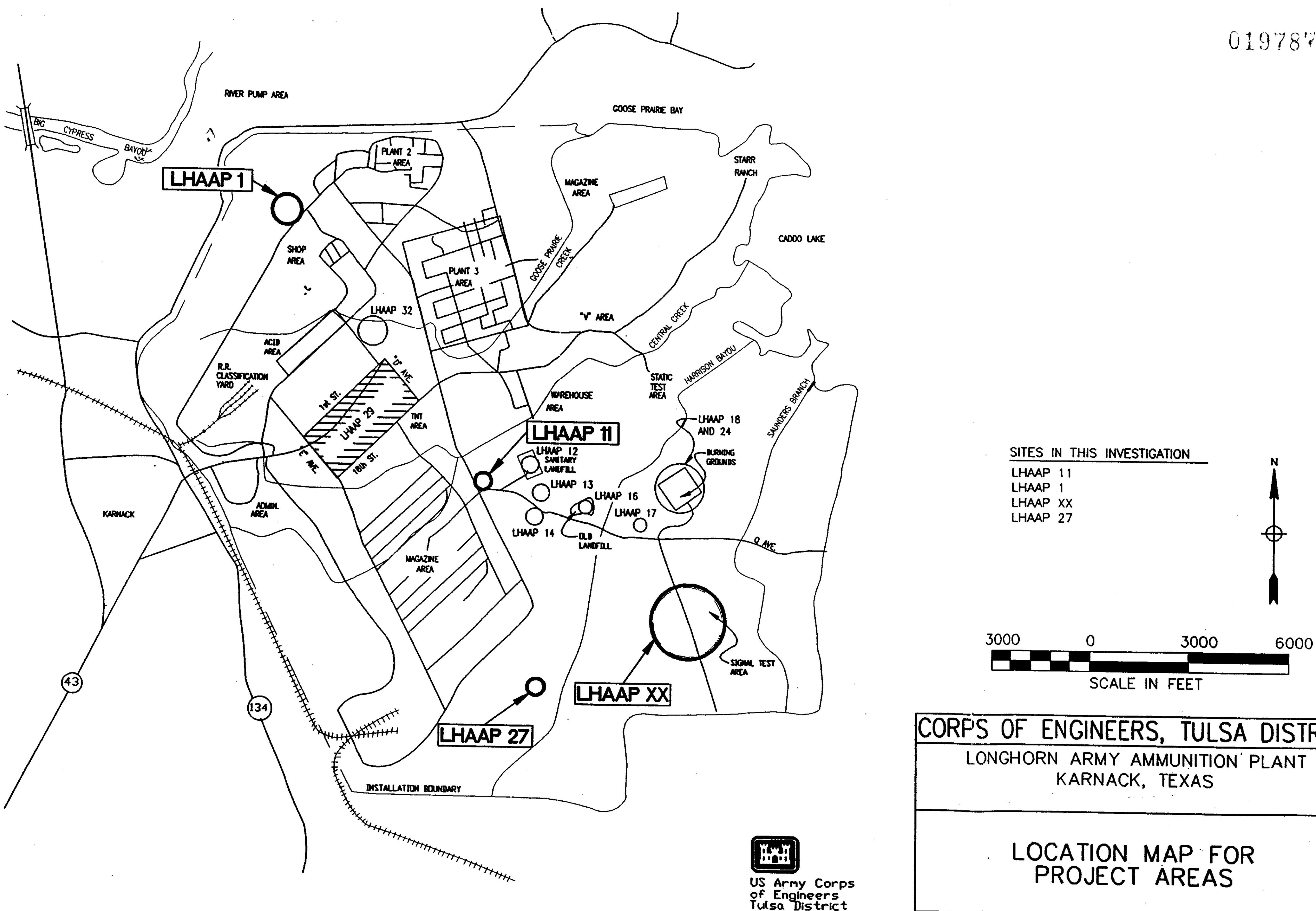

CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

LOCATION MAP FOR PROJECT AREAS

Sverdrup Environmental

FIGURE 1-3

historical activities, and investigatory findings are presented in site-specific risk assessments in Chapters 2 through 5 of this report.

1.3 GENERAL METHODOLOGY

1.3.1 General Overview. General methods, equations, assumptions, and parameter values common to all Group 1 baseline risk assessments are presented in this section. This initial presentation of information is provided to prevent repetition of methods identical for each site-specific risk assessment. Unless otherwise noted, all methods, equations, parameter values, and assumptions presented in this chapter were strictly applied to risk evaluations for all LHAAP Group 1 sites. While most methods presented in this section apply to human health evaluations, a section describing the general approach to ecological evaluation is also provided at the conclusion of this discussion.

1.3.2 Data Useability and Sampling Events. Chemical data used in quantitative risk evaluations for all Group 1 sites were limited to final validated data collected during recent remedial investigation field activities. While limited historical data were collected at some Group 1 sites during the early 1980's, that data lack appropriate data validation and quality assurance/quality control (QA/QC) information for use in quantitative risk assessment. A general discussion of results of limited historical sampling at these sites can be found in the Group 1 SCSR; however, these data were excluded from use in quantitative risk assessment.

Data resulting from remedial investigation field activities at Group 1 sites were collected during two distinct sampling periods or "phases". Details of sampling activities at each site are provided in site-specific risk assessment chapters. In general, phase I sampling activities were conducted at Group 1 sites throughout 1993, while phase II sampling was conducted during the summer of 1994. Objectives of phase II sampling efforts were generally to verify or further investigate significant findings from phase I sampling, to expand the areal extent of investigations, or to collect additional samples of specific environmental media. All data resulting from phase I and phase II sampling efforts were subjected to data validation procedures and judged to be of sufficient quality for use in quantitative risk assessment. Due to the short period between sampling events, data from both sampling phases were combined in estimating exposure concentrations for risk assessment at all sites.

The only remedial investigation data not used in Group 1 risk assessments were phase I data resulting from groundwater grab samples collected from open boreholes. Due to sampling methods, these data are not representative of groundwater quality and were therefore excluded from exposure concentration estimates involving groundwater. Groundwater data used in risk assessments for all sites were limited to those collected from on-site monitoring wells.

1.3.3 Selection of Chemicals of Potential Concern. Selection of chemicals of potential concern (COPC) for quantitative risk assessment evaluations was based on rationale described in Chapter 5 of RAGS/HHEM and Region VI supplemental guidance. Accordingly, comparison with background concentrations in environmental media was not used as a criterion for selection of chemicals for risk evaluation. While most metals concentrations in environmental media at Group 1 sites were found to approximate background levels, these chemicals were retained for use in quantitative risk assessment as a measure of overall cumulative site risk for both human health and ecological evaluations.

Consideration of background metals concentrations was, however, applied in evaluation and discussion of final risk estimates at Group 1 sites. Background values for these evaluations were those established in final reports for facility-wide background studies of LHAAP groundwater (USACE 1995a) and soils (USACE 1995b).

1.3.4 Human Health Exposure Scenarios. For human health evaluations, exposure is defined as the contact of human receptors with a chemical or physical agent (USEPA 1988). The exposure assessment process involves characterization of exposure setting, identification of exposure pathways for both current and future land uses, and quantification of exposure for human receptors (USEPA 1989). Exposure scenarios were evaluated for LHAAP Group 1 sites under both current and future land uses and are explained in detail in site-specific risk assessment chapters of this report.

One exposure scenario that is not conceivable for LHAAP sites at this time is future residential land use. Accordingly, exposure scenarios involving future residential land use were not evaluated for the facility. It is, however, possible that lands comprising LHAAP may be excessed in the future based on availability and/or environmental remediation to industrial use standards.

1.3.5 Data Distributions and Exposure Concentration Estimates. Due to uncertainties associated with estimates of human exposure concentrations, the 95% upper confidence limit (UCL) on the arithmetic average of media-specific sampling data is recommended for use in calculations of exposure concentrations (USEPA 1989). Supplemental risk assessment guidance (USEPA 1992b) has also emphasized the importance of evaluating data distributions prior to statistical calculations of confidence limits on soils data. This document stresses that most contaminant data sets from soil sampling are lognormally (rather than normally) distributed and are best suited to statistical methods appropriate for such distributions. In accordance with these recommendations and Region VI guidance, all soils data for Group 1 baseline risk assessments were assumed to be lognormally distributed. Upper 95% UCLs were calculated using lognormal distribution statistics recommended in USEPA (1992b) and Gilbert (1987). In the few cases where exposure concentrations based on the upper 95% UCL exceeded the maximum detected value of a chemical of concern, the maximum detected value was used for the exposure concentration (per RAGS/HHEM Section 6.4.1).

For groundwater exposure concentration estimates, USEPA Region VI has expressed a policy of using concentrations located near areas of highest concentration in contaminant plumes. Often, the mean of the three highest concentrations from on-site wells has been used in estimating groundwater exposure concentrations (personal communication, Region VI risk assessment staff). As groundwater contaminants were very limited at LHAAP Group 1 sites, no definable "plumes" were identified, and most chemicals of concern consisted of metals approximating background concentrations. For the sake of conservatism, highest detected concentrations of each COPC were used in pathways involving groundwater exposure at all Group 1 sites. A similar approach was used for exposure concentrations involving dermal contact with on-site surface waters.

1.3.6 Proxy Concentrations and Other Data Considerations. In accordance with RAGS/HHEM guidance (Section 5.3.3), one-half of the sample quantitation limit (SQL) was used as a "proxy" concentration for non-detect results in all calculations associated with LHAAP Group 1 risk assessments. In addition, all "J" qualified data (estimated concentrations) were included in calculations for each site. Finally, in instances where constituent concentrations differed between field samples and associated QC duplicate samples, the higher of the two values was used in exposure concentration estimate calculations. These approaches were used in an effort to provide conservatism to exposure concentrations and resulting risk estimates.

1.3.7 Range of Exposure Estimates. Chemical intake by human receptors is not only influenced by exposure concentration, but also by intake factors specific to exposed populations. Current risk assessment guidance (RAGS/HHEM) stresses the importance of the use of "reasonable maximum exposure" (RME) in human health exposure assessments. Reasonable maximum exposure is defined as "the maximum exposure that is reasonably expected to occur at a site." The guidance further states that "under this approach, some intake variables may not be at their individual maximum values but when in combination with other variables will result in estimates of the RME" (USEPA 1989). More recently, increasing emphasis has been placed on providing site managers and decision makers with an evaluation of the range of potential risk estimates at a site using both RME and central tendency (or average) exposure (CTE).

Accordingly, risk estimates based on both RME and CTE were developed for LHAAP Group 1 baseline risk assessments. Values for intake variables recommended by USEPA Region VI (provided later in this chapter) were used in these calculations.

1.3.8 Chemical Intake Equations. Chemical intakes for LHAAP Group 1 risk assessments were estimated using equations based on those provided in RAGS/HHEM. Specifically, these equations were obtained from the Supplemental Region VI Risk Assessment Guidance. Intake equations specific to each exposure pathway are provided below.

For quantification of exposure from **dermal exposure to soil and/or sediment**, the equation is:

DAD (mg/Kg-day) = [(DA-event)(EF)(ED)(SA)] / [(BW)(AT)(365 days/year)

where:

DAD = dermally absorbed dose (mg/Kg-day);
DA-event = dose absorbed per unit area per event (mg/cm^2-event) as calculated following procedures outlined in USEPA (1992c);
EF = exposure frequency (events/year);
ED = exposure duration (years);
SA = skin surface area available for contact (cm^2);
BW = body weight (Kg);
AT = averaging time (years).

For quantification of exposure from **incidental ingestion of soil and sediment**, the equation is:

Intake (mg/Kg-day) = [(Cs)(CF)(IR)(EF)(ED)] / [(BW)(AT)(365 days/year)]

where:

Cs = concentration in soil (mg/Kg);
CF = conversion factor (1E-06 Kg/mg);
IR = soil intake rate (mg/day);
EF = exposure frequency (days/year);

ED = exposure duration (years);
BW = body weight (Kg);
AT = averaging time (years).

For quantification of exposure from **inhalation of organic vapors** from soil, the equation is:

$$\text{Intake (mg/Kg-day)} = [(Cs)(1/VF)(IR)(EF)(ED)] \ / \ [(BW)(AT)(365 \text{ days/year})]$$

where:

Cs = chemical concentration of volatile compound in soil (mg/Kg);
VF = soil to air volatilization factor (m^3/Kg) as calculated according to procedure in Section 3.3.1 of Human Health Evaluation Manual, Part B (OSWER Directive 9285.7-01B);
IR = workday inhalation rate (m^3/day);
EF = exposure frequency (days/year);
ED = exposure duration (years);
BW = body weight (Kg);
AT = averaging time (years).

Where applicable, site-specific values for VF are provided in each risk assessment for Group 1 sites.

For quantification of exposure from **ingestion of particulates** released from site soils, the equation is:

$$\text{Intake (mg/Kg-day)} = [(Cs)(1/PEF)(IR)(EF)(ED)] \ / \ [(BW)(AT)(356 \text{ days/year})]$$

where:

Cs = chemical concentration in soil (mg/Kg);
PEF = particulate emission factor (m^3/Kg);
IR = workday inhalation rate (m^3/day);
EF = exposure frequency (days/year);
ED = exposure duration (years);
BW = body weight (Kg);
AT = averaging time (years).

Site-specific values for PEF are provided in each risk assessment for Group 1 sites. 019794

For quantification of exposure from **dermal contact with water**, the equation is:

$$DAD\ (mg/Kg\text{-}day) = [(DA\text{-}event)(EV)(EF)(ED)(SA)]\ /\ [(BW)(AT)(365\ days/year)]$$

where:

DAD = dermally absorbed dose (mg/Kg-day);
DA-event = dose absorbed per unit area per event (mg/cm^2-event) as calculated using procedure outlined in USEPA (1992c);
EV = event frequency (events/day);
EF = exposure frequency (days/year);
ED = exposure duration (years);
SA = skin surface area available for contact (cm^2);
BW = body weight (Kg);
AT = averaging time (years);

For quantification of exposure from **ingestion of drinking water**, the equation is:

$$Intake\ (mg/Kg\text{-}day) = [(Cw)(IR)(EF)(ED)]\ /\ [(BW)(AT)(365\ days/year)]$$

where:

Cw = concentration in water (mg/l);
IR = drinking water intake rate (l/day);
EF = exposure frequency (days/year);
ED = exposure duration (years);
BW = body weight (Kg);
AT = averaging time (years).

1.3.9 <u>Exposure Parameter Values</u>. Parameter values applied to exposure estimates for both RME and CTE for all LHAAP Group 1 sites are presented in Table 1-1. Where available, these values were obtained directly from the Region VI supplemental guidance. Where values were not available, estimates were obtained from other sources, or by estimation. Estimated values or those obtained from sources other than Region VI guidance are noted in Table 1-1.

Table 1-1. Exposure Parameter Values For Group I Baseline Risk Assessments
Longhorn Army Ammunition Plant

Pathway/Parameter	Central Tendency Exposure (CTE)	Reasonable Maximum Exposure (RME)
Water Ingestion		
Industrial intake rate (IR)	0.7 l/day	1 l/day
Soil Ingestion		
Industrial intake rate (IR)	50 mg/day	50 mg/day
Recreational intake rate (IR)	100 mg/day	100 mg/day
Air Inhalation		
Inhalation rate - adult (IR)	20 cu. m/day	20 cu. m/day
Volatilization factor (VF)	Chemical/Site-Specific[1]	Chemical/Site-Specific[1]
Particulate emission factor (PEF)	Site-Specific[1]	Site-Specific[1]
Dermal Exposure to Soil		
Adherence factor (AF)[2]	0.2 mg/cm^2 - event	1 mg/cm^2 - event
Absorption fraction (ABS)[2]	Metals - 0.01 Organics - 0.10	Metals - 0.01 Organics - 0.10
Skin surface area (SA)	5,000 cm^2/event	5,000 cm^2/event
Dermal Exposure to Water		
Permeability Constant (PC)[2]	Chemical-Specific[3]	Chemical-Specific[3]
Skin Surface Area (SA)		
Recreational exposure	6,850 cm^2 [4]	6,850 cm^2 [4]
Industrial exposure-surface water	6,850 cm^2 [4]	6,850 cm^2 [4]
Industrial exposure-groundwater	20,000 cm^2 [6]	20,000 cm^2 [6]
Event Time (ET)[2]		
Recreational exposure	1 hr/event[5]	1 hr/event[5]
Industrial exposure-surface water	1 hr/event[5]	1 hr/event[5]
Industrial exposure-groundwater	0.2 hr/event[6]	0.2 hr/event[6]

Table 1-1 (Continued)

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Pathway/Parameter	Central Tendency Exposure (CTE)	Reasonable Maximum Exposure (RME)
Event Frequency (EV)		
Recreational exposure	1 event/day[5]	1 event/day[5]
Industrial exposure-surface water	1 event/day[5]	1 event/day[5]
Industrial exposure-groundwater	1 event/day[6]	1 event/day[6]
Body Weights (BW)		
Industrial worker	70 Kg	70 Kg
Recreationist	70 Kg	70 Kg
Exposure Duration (ED)		
Industrial	9 years	25 years
Recreational	10 years	10 years
Exposure Frequency (EF)		
Industrial	250 days/year	250 days/year
Recreational	60 days/year	60 days/year
Averaging Time (AT)		
Carcinogenic Effects	70 years	70 years
Noncarcinogenic Effects	ED	ED

Note: Unless otherwise noted, all values are from USEPA Region VI Supplemental Guidance.

1 See site-specific text for values.
2 Variables used in calculation of DA event.
3 Obtained from EPA (1992).
4 Combined surface area for arms, hands, legs (wading scenario) (USEPA 1985a).
5 Estimated values for wading scenario.
6 Showering scenario.

These values were input to equations presented above for estimation of exposure in all Group 1 baseline risk assessments.

1.3.10 Toxicity Data. Once intake values were established for all exposed populations and exposure pathways, chemical-specific toxicity data were used in risk characterization. For noncarcinogenic health effects, this involved use of an oral reference dose (RfD) for oral routes of exposure and an inhalation reference concentration (RfC) for inhalation routes. For carcinogenic effects, required toxicity data included an oral slope factor (SF) or an inhalation unit risk. If available, toxicity data were first obtained from the Integrated Risk Information System (IRIS). For these risk assessments, IRIS data on-line as of February 1997 were used. If chemical-specific values were not present on IRIS, Health Effects Assessment Summary Tables (HEAST) were searched for toxicity data. Finally, a list of required toxicity data not present on IRIS or HEAST was submitted to USEPA Region VI. Where available, provisional values were provided by Region VI for these chemicals. For dermal absorption pathways, oral toxicity values were corrected for absorption efficiencies as follows: organics (1.0), metals (0.05), arsenic (1.0), cadmium (0.3) (per Region VI). Toxicity data were not available for some chemicals and routes of exposure. While risk estimates could not be calculated for these chemicals, these constituents were still carried through the evaluation process and not eliminated as COPC.

1.3.11 Inhalation Toxicity Data Conversions. For inhalation routes of exposure, RfCs and unit risks are currently expressed in terms of air concentrations (i.e., mg/m^3) and not in terms of dose (mg/Kg-day). While the USEPA warns that conversion of air concentration-based toxicity data to dose values may introduce uncertainty in risk characterization, it is often necessary to make such conversions for calculation of additive risk where dosed-based toxicity values are used for other exposure pathways. Conversion of inhalation values were conducted for LHAAP Group 1 risk assessments as follows:

$$\text{RfD-inhalation (mg/Kg-d)} = [\text{RfC (mg/m}^3) / 70 \text{ Kg}]\ [20 \text{ m}^3\text{/day}]$$

$$\text{SF-inhalation (mg/Kg-d)}^{-1} = [\text{inhalation unit risk (ug/m}^3)^{-1}]\ [70 \text{ Kg}] / [20 \text{ m}^3\text{/day}]\ [10^{-3} \text{ mg/ug}]$$

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For a few chemicals, inhalation slope factors derived by USEPA toxicity workgroups were available in HEAST. In these instances, HEAST values were used over calculated values.

1.3.12 Critical Risk Evaluation Values. For carcinogenic health effects, "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk)" (USEPA 1989). Risk estimates are obtained by multiplying daily intakes by published or calculated slope factors. Final risk estimates are obtained by summing individual risk values for all appropriate pathways. A maximum target risk range of 10^{-4} to 10^{-6} serves as a Superfund site remediation goal under the National Contingency Plan (USEPA 1989) and has generally been acknowledged as representative of acceptable risk. This range was therefore used in evaluation of carcinogenic risk estimates for LHAAP Group 1 sites.

Noncarcinogenic risk estimates are obtained by calculation of a non-cancer hazard quotient for each chemical and pathway. The hazard quotient assumes that there is a level of exposure below which it is unlikely that even sensitive subpopulations will experience adverse health effects. If the exposure exceeds this threshold, there may be concern for potential non-cancer health effects (USEPA 1989). Hazard quotients are summed for individual pathways and a hazard index (HI) obtained. Final hazard indices in excess of unity (1.0) are an indication of possible non-cancer health concerns associated with the site. This value was used in evaluation of estimated hazard indices for LHAAP Group 1 sites.

1.3.13 Ecological Risk Assessment Approach. Sections 121(b)(1) and (d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) require that decisions regarding disposition of hazardous waste sites include consideration of issues related to both human health and the natural environment (including non-human receptors). Accordingly, ecological risk assessments were prepared for each LHAAP Group 1 site. While detailed methodology and evaluation of ecological effects are provided in site-specific ecological risk assessments, an overview of the general approach and specific methods common to all sites is presented in this section.

Ecological resources at LHAAP and surrounding areas include an abundance and wide variety of terrestrial and aquatic organisms. The area is noted for its biodiversity, unique habitats, and rich history. In 1993, Caddo Lake was designated a "Wetland of International Significance" by the Ramsar Bureau in Gland, Switzerland. In addition, the U.S. Fish and Wildlife Service has classified parts of the area, including parts of LHAAP's bottomland hardwood forests, as Resource Category 1 Habitat under the Fish and Wildlife Coordination Act. These designations illustrate the ecological diversity and significance of the area. In support of ecological assessments for the facility, a summary and listing of vertebrate species, a threatened and endangered species evaluation, and a summary of major plant assemblages was prepared for LHAAP by the Caddo Lake Institute, Inc. A copy of this report is included as Appendix A.

Baseline ecological assessments for LHAAP Group 1 sites were conducted as conservative "screening level" assessments as described in Chapters 1 and 2 of current ecological risk assessment guidance (USEPA 1994). This type of assessment involves completion of the first two steps of the eight-step process described in this guidance. Using this approach, site data are used in preliminary, conservative exposure estimates and risk calculations which are heavily-biased in the direction of overestimating risk. This approach is used to ensure that sites that might pose an ecological risk are studied further and not eliminated from consideration with resulting underestimation of ecological risk. It is important to emphasize that the objective of this type of assessment is NOT to derive a "reasonable" indication of exposure and ecological risk. Rather, the sole intent of this approach is to identify, using highly conservative methodology, sites requiring further, more detailed ecological evaluation. Accordingly, results of this type of assessment should not be interpreted as representing true ecological site risks.

The only two conclusions to be drawn from a screening level assessment are: (1) there is adequate information to determine that little or no risk of adverse ecological effects exist at a site; or (2) information is not adequate to make an ecological-based decision and further, more detailed evaluation is necessary (USEPA 1994). This approach ends in a scientific/management decision point (SMDP) where risk managers use results of the assessment to either eliminate the site from further ecological consideration or pursue more detailed study of ecological impacts.

Screening-level ecological assessments for all Group 1 sites were conducted based on a site-conceptual model involving potential exposure to terrestrial organisms. As documented in each site-specific chapter, data from these sites do not indicate anticipated impacts on receiving streams or other aquatic systems. Accordingly, impacts are limited to exposure of terrestrial organisms to limited ecological "stressors" (chemicals, for these assessments) present in site soils. In an approach similar to that employed for human health evaluations, chemicals used in these assessments were not eliminated based on frequency of detection or background considerations. The only chemicals eliminated were those detected in blank samples or not identified in specific verification sampling (explained for each site). The result was evaluation of most detected chemicals at each site with evaluated chemicals identical to those used in human health assessments.

Preliminary exposure estimates for Group 1 screening-level ecological assessments were developed for both a surrogate small mammal and a bird species exposed to site contaminants via ingestion of soil and soil fauna. For small mammal exposure, the least shrew (Cryptotis parva) was used as a conservative model species. Avian exposure was conservatively modeled using estimated intake for the American woodcock (Scolopax minor). Earthworms were used as a surrogate prey species for both ecological receptors due to their high potential for bioaccumulation of soil contaminants through soil ingestion and dermal absorption, as well as availability of contaminant bioaccumulation factors for these invertebrates. Both the least shrew and the woodcock are believed to provide conservative exposure estimates due to high prey ingestion rates (resulting from elevated metabolism) and diets consisting of a high percentage of invertebrates, particularly earthworms (Merritt 1987, Terres 1991). While not a requirement for ecological screening, both species are most likely present at Group 1 sites (see Appendix A), lending further credibility to their use.

Exposure estimates for both the least shrew and the woodcock were derived using the most conservative parameter values available. For example, maximum detected chemical concentrations in site soils for each chemical of concern were used in exposure estimates. Further presentation and discussion of these values are presented in each site-specific chapter. In addition, bioavailability of all contaminants of potential concern was assumed to be 100%, the model species' home range was assumed to exist solely on the site (area use factor of 100%), diets of both species were assumed to consist solely of earthworms, and minimum body weights to maximum ingestion rates reported for each species were used. Use of these values and assumptions provide extreme conservatism to screening risk estimates for Group 1 sites.

Using methodology similar to that employed in human health exposure assessment, chemical intakes for ecological model species were estimated using equations incorporating exposure concentrations, ingestion rates, and body weights of these species. The result was estimation of a conservative chemical-specific daily dose (mg/Kg-day) for each species. Equations used in dose estimation are presented below.

For chemical intake via soil ingestion, the following equation was used for both the least shrew and the American woodcock model:

$$\text{Intake (mg/Kg-day)} = [(Cs)(SIR)(FI)(CF)] \; / \; (BW)$$

where:

Cs = chemical concentration in soil (mg/Kg);
SIR = soil ingestion rate (g dry weight/day);
FI = fraction ingested from contaminated source (unitless);
CF = conversion factor (1E-3 Kg/g);
BW = body weight (Kg).

For chemical intake via earthworm ingestion, the following equation was used for both the least shrew and the American woodcock model:

$$\text{Intake (mg/Kg-day)} = [(Cs)(BAF)(EIR)(FI)(CF)] \;/\; (BW)$$

where:

Cs = chemical concentration in soil (mg/Kg);
BAF = soil-to-earthworm bioaccumulation factor (unitless);
EIR = earthworm ingestion rate (g dry weight/day);
FI = fraction ingested from contaminated source (unitless);
CF = conversion factor (1E-3 Kg/g);
BW = body weight (Kg).

Exposure parameter values used in these equations for all Group 1 ecological assessments are presented in Table 1-2. Earthworm bioaccumulation factors obtained for all collective chemicals of concern for Group 1 sites were those obtained from the scientific literature. A listing of these values and associated references is provided in Appendix B.

Table 1-2. Exposure Parameter Values for Group 1 Screening-Level Ecological Risk Assessments, Longhorn Army Ammunition Plant

Parameter	Model Species	
	Least Shrew	American Woodcock
Earthworm Ingestion Rate (EIR)	1.25g dry wt/day (Merritt 1987)	63g dry wt/day (Stickel et al. 1965)
Soil Ingestion Rate (SIR)	0.13g dry wt/day[1]	6.55g dry wt/day[1]
Fraction Ingested From Sources (FI)	1[2]	1[2]
Body Weight (BW)	0.005 Kg (Merritt 1987)	0.177 Kg (Stickel et al. 1965)
Soil-to-Earthworm Bioaccumulation Factor (BAF)	Chemical-Specific[3]	Chemical-Specific[3]

[1] Assumed to be 10.4% of earthworm intake (USEPA 1993a).
[2] Assumes site includes 100% of home range.
[3] See Appendix B.

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Upon establishment of daily doses for each species, the hazard quotient method of risk estimation was used in calculating screening-level risk values. This consisted of comparing estimated intake values with toxicity values in a manner similar to that used in human health risk assessment. Reference toxicity values (RTVs) for ecological screening of each chemical were developed based on values obtained from literature. While a detailed discussion of methods of estimating these values is presented in Chapter 2 of this document, RTVs for screening purposes were generally based on documented and/or best conservatively estimated no-observed-adverse-effects-levels (NOAELs) for closely-related species. Hazard quotients for each indicator species and chemical were obtained by dividing chemical intakes by appropriate RTVs.

Finally, hazard quotients for all chemicals of ecological concern were summed to obtain a total ecological screening hazard index. If this value exceeded unity (1.0), individual chemicals driving the screening risk estimate were evaluated. In many cases, this included consideration of metals background values and comparisons with site soils data. Areas of uncertainty regarding estimated risk values were likewise provided for each site.

Screening-level ecological assessments for each Group 1 site concluded by providing risk managers with information necessary for ecologically-related site decisions. This included conclusions and recommendations regarding the potential for ecological concerns at the site and the need (or lack thereof) for further ecological evaluation.

1.3.14 Uncertainties. Evaluation of baseline risk assessment results should include consideration of areas and degrees of uncertainty associated with risk estimates (USEPA 1989). While every attempt was made to minimize areas of uncertainty with the use of conservative assumptions and estimation techniques throughout LHAAP Group 1 risk assessments, numerous areas of uncertainty remain. These areas of uncertainty are documented throughout this report and should be considered in site-related decisions.

CHAPTER 2
LHAAP SITE 1
(INERT BURNING GROUNDS)

HUMAN HEALTH EVALUATION

2.1 SITE DESCRIPTION

2.1.1 Site History. The Inert Burning Grounds (LHAAP Site 1) were initially used by Monsanto Chemical Company during World War II for burning of trash, ashes, scrap lumber, and waste from burned 2,4,6-TNT. It is possible that bulk 2,4,6-TNT may also have been burned at the site. The site remained inactive between August 1945 and February 1952 when LHAAP was in standby status, but was used for a few years during the 1950's by Universal Match Corporation for burning of various wastes, including photo flash powder. Intermittent, small-scale burning operations may have continued at the site into the early 1960's, although most burning at the plant was transferred to an alternate burning location. It is suspected that burning operations were conducted in one or more burn pans or pits (exact locations unknown) that were subsequently filled or covered without removal of burn residues. It is also possible that some wastes may have been dumped without burning and were subsequently covered by or mixed with fill material.

2.1.2 Site Location and Features. Site 1 covers an area of approximately 5.5 acres and is located in the extreme northwest corner of LHAAP near the intersection of Avenue P and 32nd Street (Figure 1-3). A map showing surface topography, surface drainage patterns, suspected site limits, and other site features is presented later in this chapter. In general, surface drainage is to the south and east via minor drainage ditches. Distances to major creeks are approximately 0.7 miles to Big Cypress Bayou off the installation to the northwest and 0.6 miles to Goose Prairie Creek to the south and east (Figure 1-3). Distance from the site to the northwestern boundary of LHAAP is approximately 0.4 miles. The majority of the site is covered with heavy timber and undergrowth that has developed since the site was last used. The area surrounding Site 1 on LHAAP is heavily wooded and undeveloped.

Geology and hydrogeology at Site 1 are described in detail in the Group 1 SCSR. In summary, surficial soils encountered across the site consisted of reddish-brown sandy clays with a little silt to a depth of approximately 5 to 10 feet below ground surface. Depth to groundwater varies across the site but was generally encountered at a depth of approximately 10 feet below ground surface. A hydraulic gradient of 0.012 feet/feet in an easterly direction was calculated at the site with horizontal groundwater flow velocity estimated at 0.23 feet/day.

2.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2.2.1 Remedial Investigation Activities. In 1993, phase 1 remedial investigations were conducted at Site 1 in two stages. The site section to the south and east was investigated by Ebasco Services, Inc. (Ebasco), while the site section to the north and west was investigated by Roy F. Weston (Weston). In 1994, phase 2 remedial investigations were conducted by Sverdrup Environmental, Inc. (Sverdrup). All information pertaining to sampling methods, boring logs, well diagrams, geotechnical data, survey information, and analytical data are provided in the Group 1 SCSR. While appropriate sections of the SCSR should be consulted for specific details, sampling activities pertinent to this baseline risk assessment are briefly summarized below.

In 1993, Ebasco collected forty-one (41) soil samples (8 surface and 33 subsurface) at varying depth intervals within unsaturated soils from eight (8) soil borings extending to a depth of 10 to 30 feet. As the suspected source of contamination was believed to be burned explosives waste residues and other wastes that had been covered or mixed with fill materials, surficial soil samples were collected at depths of 0 to 2.5 and 2.5 to 5.0 feet below ground surface. Groundwater grab samples were collected from each boring. Groundwater was also sampled from existing monitoring well 104 at the site. Surficial (0- to 6-inch depth) ditch "sediment" and surface water samples were collected from seven (7) locations.

Also as part of phase 1 sampling activities, Weston collected seventy-four (74) soil samples (9 surface and 65 subsurface) within unsaturated soils from nine (9) soils borings. Five (5) of the borings were completed as monitoring wells screened in the shallow water-bearing transmissive unit beneath the site, and groundwater samples were collected. Groundwater grab samples were collected from the four (4) borings which were not completed as monitoring wells. In addition, Weston collected three (3) ditch sediment (0- to 6-inch depth) and surface water samples. All samples of all environmental media collected during phase 1 efforts were analyzed for volatile organic compounds (VOCs) (EPA Method 8240); semivolatile organic compounds (SVOCs) (EPA Method 8270); high explosives (EPA Method 8330); total metals, including silver, barium, cadmium, chromium, nickel, and antimony (EPA Method 6010); arsenic (EPA Method 7060); mercury (EPA Method 7470); lead (EPA Method 7421); selenium (EPA Method 7740); and thallium (EPA Method 7841).

In 1994, Sverdrup conducted phase 2 sampling of LHAAP Site 1. Sampling efforts included the collection of three (3) ditch sediment samples, five (5) surface (0- to 6-inch depth) soils samples, and two (2) groundwater samples from one (1) newly installed shallow monitoring well and one (1) existing well. All sediment samples were analyzed for VOCs, SVOCs, explosives, total metals (same as above), nitrates, chlorides, sulfates, and pH. Surface soil samples were analyzed for barium, lead, and selenium only. Groundwater samples were analyzed for VOCs, SVOCs, explosives, total metals (same as soils), nitrates, chlorides, and sulfates. All phase 1 and phase 2 sampling locations, well locations, and other pertinent site information are shown in Figure 2-1.

2.2.2 Remedial Investigation Results. Complete results of all remedial investigation sampling activities are provided in detail in the Group 1 SCSR. Results forming the basis for this risk assessment are summarized below.

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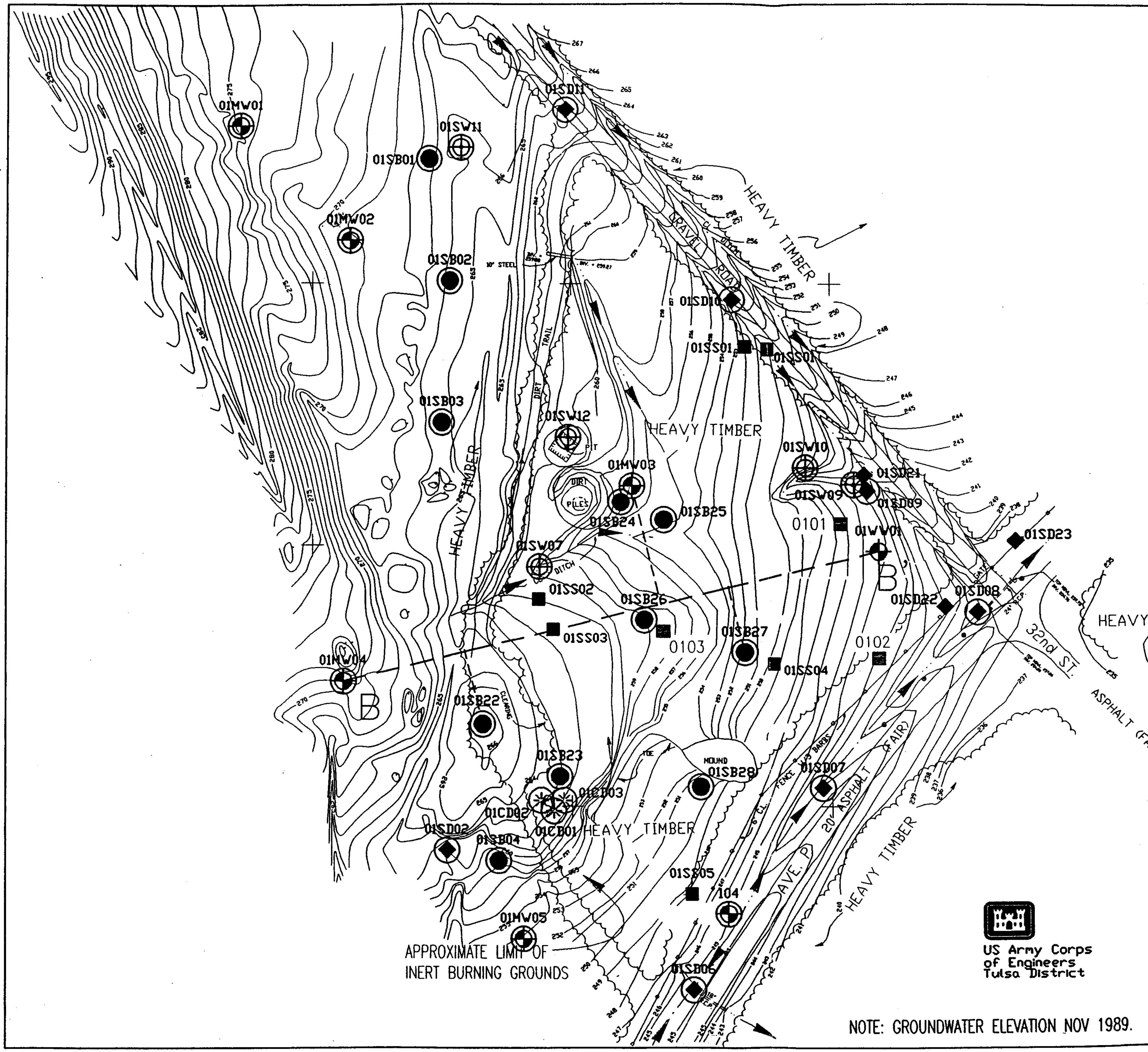

LEGEND

- SURFACE SOIL SAMPLE (PREVIOUS)
- SURFACE WATER FLOW DIRECTION
- SURFACE WATER/ SEDIMENT SAMPLE (PREVIOUS)
- MONITORING WELL (EXISTING)
- CONSTRUCTION DEBRIS SAMPLE (PREVIOUS)
- SOIL BORING (PREVIOUS)
- SURFACE WATER/ SEDIMENT SAMPLE (PHASE 2)
- MONITORING WELL (PHASE 2)
- SURFACE SOIL SAMPLE (PHASE 2)
- SURFACE WATER SAMPLE (PREVIOUS)

US Army Corps of Engineers Tulsa District

NOTE: GROUNDWATER ELEVATION NOV 1989.

CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

LHAAP 1
INERT BURNING GROUND
SITE LAYOUT AND
SAMPLE LOCATIONS

Sverdrup Environmental

FIGURE 2-1

Constituents detected in groundwater at LHAAP Site 1 are summarized in Table 2-1. Detected organics included low levels and infrequent detections of 2-butanone, acetone, isophorone, 2,6-dinitrotoluene (detected in semivolatiles analysis but not explosives analysis), and bis(2-ethylhexyl)phthalate. Only bis(2-ethylhexyl)phthalate has an established drinking water Maximum Contaminant Level (MCL) at 0.004 mg/l which was slightly exceeded in one estimated concentration of 5 ug/l. Acetone, 2-butanone, and bis(2-ethylhexyl)phthalate are considered common laboratory contaminants (USEPA 1989) and are compared to levels in blank samples later in this section.

Table 2-1. Chemicals Detected in Groundwater
Site 1, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[1]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[2]
Organics (ug/l)				
2-Butanone	2/11	10-50	12-19	--
Acetone	2/11	10-100	11B-18	--
Isophorone	1/11	9-10	1J	--
2,6-Dinitrotoluene	1/11	0.31-10	14[3]	--
Bis(2-ethylhexyl)phthalate	4/11	9-10	1J-5J	--
Metals (mg/l)				
Barium	11/11	--	0.07-0.31	0.02-1.99
Chromium	3/11	0.01-0.05	0.01-0.056	0.01-0.11
Lead	9/11	0.002-0.005	0.0008-0.041	0.003-0.3
Nickel	2/11	0.02-0.05	0.048-0.062	0.02-0.06

[1] Includes quality control duplicate samples.
[2] Range of detected concentrations from Final Groundwater Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).
[3] Detected in semivolatiles analysis but not explosives analysis.

Detected total metals in groundwater included barium, chromium, lead, and nickel. While lead has no established MCL (but does have action level of 0.015 mg/l), all detected concentrations of barium, chromium, and nickel were well below their MCLs of 2, 0.1, and 0.1 mg/l, respectively. All concentrations of total metals were also at or below background levels established for LHAAP (Table 2-1).

Chemicals detected in Site 1 soil samples at depths relevant to risk assessment evaluations are summarized in Table 2-2. This summary includes all soil samples collected at the site to a depth of 5 feet below ground surface. This depth range is included as it was used in future land use scenarios for the site (explained later in this text). Detected organics included low levels of several VOCs, phthalate esters, and polynuclear aromatic hydrocarbons (PAHs). A number of metals were detected at concentrations which sometimes exceeded background levels. No explosives were ever detected in site soils at any depth.

Chemicals detected in Site 1 surface waters are summarized in Table 2-3. Detected organics included one-time detections of low levels of acetone and toluene. Total metals detected in site surface waters included arsenic, barium, chromium, lead, and nickel.

A summary of constituents detected in ditch surface sediments is presented in Table 2-4. Detected chemicals and concentrations were very similar to those detected in site soils (compare with Table 2-2). Significant accumulation or concentration of these constituents in ditch sediments was not apparent.

2.2.3 Selection of Chemicals of Potential Concern. Environmental data sets described above were evaluated for selection of chemicals for use in quantitative risk assessment. Selection of chemicals was based on rationale described in Chapter 5 of RAGS/HHEM and discussed in Chapter 1 of this document. Justification for elimination of several media-specific chemicals is provided in this section.

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Table 2-2. Chemicals Detected in Soils[1]
Site 1, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[2]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[3]
Organics (ug/Kg)				
Acetone	4/36	10-100	20-600B	--
Methylene Chloride	3/36	5	6B-20	--
Toluene	2/36	5	6.7-8.9	--
Xylene	2/36	5	6-30.6	--
Phenanthrene	1/36	290-660	763	--
Di-n-butylphthalate	9/36	330	110JB-3,580	
Flouranthene	2/36	330-660	530-1,620	--
Pyrene	2/36	330-660	370-1,740	--
Benzo(a)anthracene	2/36	330-660	230J-753	--
Chrysene	1/36	330-660	240J	--
Bis(2-ethylhexyl)phthalate	3/36	330-660	396-955	--
Benzo(k)flouranthene	2/36	330-660	530-762	--
Benzo(b)flouranthene	2/36	330-660	160J-887	--
Benzo(a)pyrene	2/36	330-660	340-829	--
Ideno(1,2,3-cd)pyrene	2/36	330-660	240J-560	--
Dibenzo(a,h)anthracene	1/36	330-660	59J	--
Benzo(g,h,i)perylene	2/36	330-660	230J-484	--
Metals (mg/Kg)				
Antimony	1/36	0.12-1.0	10.2	7.5
Arsenic	36/36	--	0.2-8.8	1.7-36.8
Barium	41/41	--	23.6-188	22.0-287
Chromium	36/36	--	5.1-32.1	3.2-26.2
Lead	41/41	--	3-75	1.0-17.4
Mercury	20/36	0.069-0.1	0.01-0.15	0.25
Nickel	34/36	1.6-1.7	2.6-23.1	1.5-19.1
Selenium	28/41	0.1-1.2	0.1-0.99	0.5

[1] Includes all soil samples to depth of 5 feet.
[2] Includes quality control duplicate samples.
[3] Range of detected concentrations of both surface (0-0.5 feet) and subsurface (>0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995b).

Table 2-3. Chemicals Detected in Surface Waters
Site 1, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection*	Sample Quantitation Limits	Range of Detected Contaminants
Organics (ug/l)			
Acetone	1/11	10-100	11B
Toluene	1/11	5	6.3
Metals (mg/l)			
Arsenic	5/11	0.01	0.0028-0.02
Barium	11/11	--	0.013-0.47
Chromium	1/11	0.02-0.05	0.061
Lead	8/11	0.005	0.0054-0.045
Nickel	1/11	0.02-0.05	0.02

* Includes quality control duplicate samples.

Table 2-4. Chemicals Detected in Ditch Surface Sediments
Site 1, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[1]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[2]
Organics (ug/Kg)				
2-Butanone	2/16	10-50	13-24	--
Acetone	5/16	10-100	12B-103	--
Methylene Chloride	2/16	5-14	5-13	--
Benzoic Acid	3/16	330-1,700	1,200J-2,700	--
Phenanthrene	1/16	330-480	1,060	--
Di-n-butylphthalate	6/16	330-693	77JB-7,437	
Flouranthene	1/16	330-480	1,580	--
Pyrene	1/16	330-480	1,130	--
Benzo(a)anthracene	1/16	330-480	420	--
Chrysene	1/16	330-480	550	--
Bis(2-ethylhexyl)phthalate	1/16	330-480	1,700	--
Benzo(b)flouranthene	1/16	330-480	480	--
Benzo(k)flouranthene	1/16	330-480	390	--
Benzo(a)pyrene	1/16	330-480	390	--
Metals (mg/Kg)				
Antimony	1/16	0.22-1	1.0	7.5
Arsenic	16/16	--	0.54-7.5J	2.3-29.7
Barium	16/16	--	13.4-88.4	35.1-287
Cadmium	1/16	0.5-1	1.0	1.25
Chromium	16/16	--	4.4-24.7	3.2-22.8
Lead	16/16	--	3.6-19.0	2.6-17.4
Mercury	5/16	0.074-0.14	0.01-0.04	0.25
Nickel	15/16	1.0-1.8	1.2-11.1	1.5-6.3
Selenium	10/16	0.1-0.72	0.1-1.1	0.5
Silver	1/16	1.0-2.5	1.0	1.3

[1] Includes quality control duplicate samples.
[2] Provided for comparison - range of detected concentrations in surface soils (0-0.5-foot depth) from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995b).

Section 5.5 of RAGS/HHEM states that, under certain conditions, chemicals of concern may be eliminated based on comparison with concentrations in blank samples. If blanks contain detectable concentrations of common laboratory contaminants (defined by the USEPA as acetone, 2-butanone, methylene chloride, toluene, and the phthalate esters), then sample results should be considered as positive only if concentrations in the sample exceed ten (10) times the maximum amount detected in any blank. For chemicals not considered common laboratory contaminants, results are considered positive only if the concentration of the chemical in the sample exceeds five (5) times the maximum amount in any blank sample (USEPA 1989).

Rationale described above was applied to all Site 1 data in selection of chemicals of concern. For surface water, the laboratory method blank associated with the single detection of acetone in this media (5 ug/l) was reported to contain 18 ug/l acetone. As the detected value was less than 10 times the amount in this blank, acetone was eliminated as a COPC in surface water. Similarly, acetone was eliminated as a COPC in site sediments. While concentrations of 20 and 12 ug/Kg were detected in phase 1 samples SD-03 and SD-02, respectively, acetone was reported in the method blank associated with these samples at a concentration of 18 parts per billion (ppb). Detected acetone concentrations of 94, 57, and 104 ug/Kg in phase 2 samples were likewise associated with 26 ug/l acetone in a phase 2 equipment rinsate blank (sample 01SD21ER). Di-n-butylphthalate was commonly detected in a number of blank samples at concentrations as high as 504 ppb. Accordingly, this common lab contaminant was eliminated as a COPC for soils and sediments.

For LHAAP Site 1 groundwater, estimated (J-qualified) concentrations of bis(2-ethylhexyl) phthalate ranging from 1J to 5J ug/l were all associated with an equipment blank sample concentration of 1J ug/l. Accordingly, bis(2-ethylhexyl)phthalate was eliminated as a COPC in groundwater. While not a common lab contaminant, lead was detected in two phase 1 equipment blanks (MW-01-1001EB and MW-04-1001EB) at a maximum concentration of 0.026 mg/l. All nine (9) detected concentrations of lead in groundwater reported from phase 1 sampling were less than five (5) times this concentration, resulting in elimination of lead as a COPC for groundwater.

During phase 1 groundwater sampling, 2,6-dinitrotoluene was detected at 14 ug/l in a sample from monitoring well MW-04 in analysis for SVOCs (Method 8270), but not in explosives analysis (Method 8330). To further investigate the possible presence of this explosive compound in groundwater at the site, this well was resampled during phase 2 and an additional well was installed and sampled at the site (01WW01). This compound was not detected in either SVOA or explosives analyses for samples from either well. These confirmatory findings, combined with no detections of this chemical in site soils, resulted in elimination of 2,6-dinitrotoluene as a COPC in Site 1 groundwater.

With the exception of the eliminated chemicals described above, all detected constituents listed in Tables 2-1 through 2-4 were retained as COPC for quantitative risk analysis.

2.3 EXPOSURE ASSESSMENT

2.3.1 Characterization of Exposure Setting. Site 1 at LHAAP is located in a heavily-wooded, remote portion of the plant. Work activities associated with LHAAP's mission are far removed from the area, and no maintenance activities occur at the site. The site is also a considerable distance from the plant boundary or other areas of activity.

Both surface and groundwater flow from the site occur in an easterly direction (Figure 2-1). This precludes transport of limited surface or subsurface contaminants to off-plant receptors or to areas of significant human activity.

2.3.2 Identification of Exposure Pathways. Necessary elements of an exposure pathway include a source of contamination, transport medium, routes of exposure, and human receptors at exposure points (USEPA 1989). Absence of necessary elements results in incomplete exposure pathways indicating that exposure will not occur and no adverse impacts on human health exist for that pathway.

Exposure pathways considered for evaluation for this baseline risk assessment are listed in Table 2-5. Given existing land use activities at the site, the only conceivable current land use exposure scenario would involve recreational use of the area. While even this is extremely limited at present, occasional deer hunting (during season weekends) is allowed at LHAAP and could result in limited use of the area. It is also possible that the area could be frequented by an occasional hiker, bird-watcher, or other recreationist, although current security measures at the plant preclude unlimited public access to these areas. In light of the possibility of limited current recreational activities at the site, an exposure scenario involving recreational use of the area was evaluated for this assessment.

Exposure pathways under current recreational land use could include dermal contact with site soils and ditch surface sediments, incidental ingestion of surficial soils, inhalation of soil particulates, and inhalation of organic vapors released from soils (given limited detection of VOCs at the site). While on-site surface waters are confined to drainage ditches containing water after rainfall events, dermal contact with these waters through wading is conceivable and was evaluated for this assessment. As these waters are of insufficient depth for swimming, the potential for ingestion of surface waters while swimming was considered low and was therefore not evaluated for this site.

While future land use practices at the site could include continued recreational use, future industrial development of the area is also conceivable. This scenario could occur as a result of construction required for mission changes at LHAAP or lease or excess of lands for industrial development. Industrial land use could potentially include excavation of site soils for construction purposes, other earth-moving activities, and maintenance functions resulting in exposure to industrial workers.

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Table 2-5. Summary of Exposure Pathways
Site 1, Longhorn Army Ammunition Plant

Potentially Exposed Population	Exposure Route, Medium , and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
CURRENT LAND USE			
Plant Workers	Various	No	No current work activities at or near site. Pathway is incomplete.
Off-Plant Residents, Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Dermal contact with surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Incidental ingestion of surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of vapors from soils and ditches	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of soil and ditch particulates	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Dermal contact with surface waters	Yes	Potential recreational activities at site. Short-term presence of surface waters. Pathway potentially complete.
On-Site Recreationists	Ingestion of surface water	No	No on-site surface water of depth suitable for swimming. Pathway incomplete.
FUTURE LAND USE			
Off-Plant Residents/ Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Various as listed under current land use	Yes	Potential future recreational activities at site. Pathways potentially complete.

Table 2-5 (Continued)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
FUTURE LAND USE (Continued)			
On-Site Workers	Dermal contact with surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Incidental ingestion of surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of organic vapors from soils and ditches	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of surface and subsurface soil and ditch sediment particulates	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Dermal contact with surface waters	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Ingestion of surface waters	No	No conceivable activities completing this pathway.
On-Site Workers	Ingestion of groundwater from on-site well	Yes	New well installation conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Dermal contact with groundwater	Yes	Showering conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Inhalation of volatiles from groundwater	No	Extremely low concentrations of volatiles and lack of showering/ dishwashing under industrial scenario minimize significance of this pathway.
On-Site Residents	Various	No	Residential land use not conceivable. Excessed property based on availability and/or remediation to industrial standards.

While exposure factors (i.e., exposure duration and frequencies) would most likely differ, 019818 exposure pathways under a future industrial land use scenario could include all those described above for recreational use. Despite the existence of a current water supply source at LHAAP, it is also plausible that an on-site water supply well could be installed at the site if industrial development were to occur. This would result in the additional exposure pathways of groundwater ingestion and dermal contact with groundwater (primarily through showering) for industrial site workers. As such, these pathways were evaluated under future industrial land use conditions. While low levels of VOCs were detected in groundwater at Site 1, a probable lack of dishwashing or other activities resulting in significant volatilization of organics from groundwater used as a water source precluded evaluation of this pathway for the site. Given the low concentrations of VOCs detected in groundwater at the site, this was not considered an area of significant uncertainty.

Exposed populations for all land use scenarios were assumed to be composed entirely of adults, with no sensitive subpopulations (children, elderly, etc.) present on-site. As current recreational use at the site is primarily limited to deer hunting, small children would most likely not participate in these activities. Likewise, children would not be expected on-site under a future industrial scenario. As such, risk evaluations for this assessment were conducted for adult populations only.

2.3.3 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

2.3.3.1 Summary of Exposure Concentrations. Estimates of exposure concentrations for all environmental media and exposure pathways were developed using methodology described in Chapter 1 of this report. A brief explanation of rationale used in estimating exposure concentrations for pathways involving site soils is provided below. 019819

For purposes of exposure estimation, surface soil is generally defined as the shallowest depth that can be practically sampled (i.e., 6 inches or 1 foot) (USEPA 1989; Region VI Supplemental Guidance). As initial soil sampling conducted at LHAAP Site 1 was conducted to investigate the nature and extent of potential contamination from wastes which were reportedly covered over or mixed with fill material, soil samples of surficial materials were initially collected at depths from 0 to 2.5 feet and 2.5 to 5.0 feet below ground surface. Samples from depositional areas of drainage ditches were collected at depths of 0 to 6 inches below ground surface as an indication of potential transport of surface contaminants from site soils. Due to the infrequent and low levels of detected contaminants using this approach, extensive sampling of shallower layers was not conducted during phase 2. As a result, most "surface" soils data for this site were obtained from the 0- to 2.5-foot range. Use of these data for surface soil exposure concentration estimates adds some degree of uncertainty to these estimates, but is not considered a significant deficiency given site conditions.

Another consideration involves the use of surface materials collected from site drainage ditches in exposure estimates. These ditches represent shallow drainage pathways transversing or bordering the site which generally contain water for a short time only after rainfall events. While the term "sediment" has been applied to samples from these shallow ditches, from an exposure standpoint, these surficial materials are similar to site soils in that they provide a source for volatilization of vapors, release of particulates, and serve as areas of potential exposure via ingestion and dermal contact. As the underlying basis for exposure at a site involves the use of spatially averaged soil concentrations contacted over time (USEPA 1992b), these ditches represent areas of potential soils exposure that should be accounted for in exposure estimates based on spatial averages. For these reasons, data obtained from ditches were combined with those from site soils for all pathways involving direct or indirect (through inhalation) exposure. The fact that these data are based on soil depths of 0 to 6 inches may also partially mitigate uncertainties associated with use of soils samples collected at slightly deeper depths when combined with these data for purposes of surface soil exposure estimation.

Based on rationale presented above, estimation of exposure concentrations involving site soils under current recreational land use was obtained by applying principles presented in Chapter 1 to soils data from uppermost sampling intervals in site soils and surficial ditch sediments. Estimated exposure concentrations for all site media for the current recreational land use scenario are presented in Table 2-6.

As future industrial land use could potentially involve soil excavation and earth-moving activities, the potential exists for exposure to soils at greater depths under this scenario. Accordingly, soils data from 2.5- to 5.0-foot depths were incorporated into these exposure estimates. Concentrations from 0- to 2.5- and 2.5- to 5.0-foot depths from each soil boring were averaged to obtain a single point estimate over a 5-foot depth for that boring. These values were then combined with ditches data and exposure estimates based on the 95% UCL calculated. Exposure concentration estimates for all pathways under the future industrial land use scenario are presented in Table 2-7.

2.3.3.2 <u>Estimation of Chemical Intakes</u>. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations presented in Chapter 1. All intake equations and variable values used in intake estimates for varying exposure scenarios were presented in this chapter.

Chemical- and site-specific volatilization factors (VF) for intake estimates involving inhalation of VOCs released from site soils were calculated according to procedures outlined in Section 3.3.1 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of chemical- and site-specific input variables, all default values provided in the guidance were used. For Site 1, the following values for VF (m^3/Kg) were obtained: methylene chloride - 3,866; acetone - 10,609; toluene - 7,609; xylene - 6,288; 2-butanone - 8,929.

Table 2-6. Summary of Exposure Concentrations, **Current Land Use**
Site 1, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Acetone	0.101	Concentrations are the 95% upper confidence limit on average concentrations in site surface soils and ditches assuming lognormal data distribution.
Methylene Chloride	0.004	
Toluene	0.003	
Xylene	0.003	
2-Butanone	0.023	
Benzoic Acid	1.112	
Phenanthrene	0.259	
Fluoranthene	0.318	
Pyrene	0.297	
Benzo(a)anthracene	0.227	
Chrysene	0.207	
Bis(2-ethylhexyl)phthalate	0.263	
Benzo(k)flouranthene	0.241	
Benzo(b)flouranthene	0.233	
Benzo(a)pyrene	0.234	
Ideno(1,2,3-cd)pyrene	0.208	
Dibenzo(a,h)anthracene	0.059*	
Benzo(g,h,i)perylene	0.203	

Table 2-6 (Continued)

Populations/Pathways	Exposure Concentrations	Comments
Recreationists (Continued) **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Antimony	0.56	
Arsenic	4.28	
Barium	67.38	
Cadmium	0.52	
Chromium	14.88	
Lead	17.13	
Mercury	0.08	
Nickel	7.04	
Selenium	0.42	
Silver	0.96	
Recreationists **Dermal contact with surface water**		
	mg/l	
Toluene	0.006	Concentrations are maximum detected concentrations in on-site surface water.
Arsenic	0.02	
Barium	0.47	
Chromium	0.061	
Lead	0.045	
Nickel	0.02	

* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).

Note: Soils data from 0-5-foot depth used in organic vapor inhalation exposure calculations (see Table 2-7).

Table 2-7. Summary of Exposure Concentrations, **Future Land Use**
Site 1, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
<u>Recreationists</u>		
All exposure pathways	Same as listed in Table 2-6 (Current Land Use).	
<u>Industrial Workers</u>		
Incidental ingestion of soil **Dermal contact with soil** **Inhalation of particulates** **Inhalation of organic vapors**		
	mg/Kg	
Acetone	0.099	Concentrations are the 95% upper confidence limit on average concentrations of ditch soils and site soils to depth of 5 feet assuming lognormal data distribution.
Methylene Chloride	0.004	
Toluene	0.003	
Xylene	0.003	
2-Butanone	0.023	
Benzoic Acid	1.112	
Phenanthrene	0.230	
Fluoranthene	0.258	
Pyrene	0.243	
Benzo(a)anthracene	0.203	
Chrysene	0.200	
Bis(2-ethylhexyl)phthalate	0.233	
Benzo(k)flouranthene	0.206	
Benzo(b)flouranthene	0.206	
Benzo(a)pyrene	0.204	
Ideno(1,2,3-cd)pyrene	0.187	
Dibenzo(a,h)anthracene	0.059*	
Benzo(g,h,i)perylene	0.186	

Table 2-7 (Continued)

Populations/Pathways	Exposure Concentrations	Comments
Industrial Workers (Continued) **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates** **Inhalation of organic vapors**		
	mg/Kg	
Antimony	0.66	
Arsenic	3.95	
Barium	65.75	
Chromium	15.23	
Cadmium	0.52	
Lead	12.95	
Mercury	0.07	
Nickel	7.19	
Selenium	0.42	
Silver	0.95	
Industrial Workers **Dermal contact with surface water**		
	mg/l	
Toluene	0.006	Concentrations are maximum detected concentrations in on-site surface water.
Arsenic	0.02	
Barium	0.47	
Chromium	0.061	
Lead	0.045	
Nickel	0.02	

Table 2-7 (Continued)

Populations/Pathways	Exposure Concentrations	Comments
Industrial Workers **Ingestion of groundwater** **Dermal contact with groundwater**		
	mg/l	
2-Butanone	0.019	Concentrations are maximum detected concentrations in site groundwater.
Acetone	0.018	
Isophorone	0.001	
Barium	0.31	
Chromium	0.056	
Nickel	0.062	
* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).		

A site-specific value for the particulate emission factor (PEF) used in evaluating inhalation of particulates released from site soils (see equation, Chapter 1) was likewise calculated for LHAAP Site 1 using methodology presented in Section 3.3.2 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of site dimensions, all default variable values presented in this guidance were used in this calculation. The resulting PEF for Site 1 was 1.73E9m^3/Kg.

Estimated intake rates for all COPC across all exposure pathways are presented in the "Risk Characterization" section of this document.

2.3.4 Identification of Uncertainties. Exposure assessment requires frequent use of professional judgement and estimation of variables used in risk quantification. This frequently leads to varying degrees of uncertainty in final risk estimates. Areas of uncertainty and estimated magnitude of effects of these areas in exposure assessment for this assessment are listed in Table 2-8. These factors should always be considered in evaluating conclusions of this baseline risk assessment for LHAAP Site 1.

An area of uncertainty in exposure assessment for this study concerns judgmental selection of soils and ditch sampling locations. This may result in bias in development of exposure concentrations for on-site human receptors. While the potential exists for over- or underestimation of exposure with use of these data, it is likely that overestimation may result due to collection of data in areas with highest potential for contamination. In addition, issues regarding use of soils data from depths greater than those frequently used for evaluating surface exposure add uncertainty to these estimates as discussed in previous sections of this report.

As indicated in Table 2-8, many areas of uncertainty associated with this baseline risk assessment may result in overestimation of risk. This results from the practice of employing conservative assumptions throughout exposure assessment and evaluation.

2.4 TOXICITY ASSESSMENT

2.4.1 General Toxicity Information. The purpose of this toxicity assessment is to weigh available evidence regarding the potential for contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects (USEPA 1989). Sources of information concerning health effects (carcinogenic and noncarcinogenic) include controlled epidemiologic investigations, clinical studies, and experimental animal studies.

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Table 2-8. Summary of Areas of Uncertainty for Exposure Assessment
Site 1, Longhorn Army Ammunition Plant

Assumption	Effect on Exposure*: Potential Magnitude for Over-estimation of Exposure	Potential Magnitude for Under-estimation of Exposure	Potential Magnitude for Over- or Under-estimation of Exposure
Environmental Sampling and Analysis			
Sampling locations judgmental (nonrandom). May result in bias in data.			Moderate
Sufficient sample numbers may not have been collected.		Low	
Passage of time since soils data collection may have resulted in release of VOCs and currently lower concentrations.	Low		
Low levels of VOCs in groundwater data may be result of lab contamination.	Low		
Use of soil depths greater than 0-6 inches in surface exposure estimation.			Low
Exposure Parameter Estimation			
Standard assumptions used in intake calculations may not reflect actual exposure.			Moderate
Use of maximum detected values for pathways involving exposure to groundwater and surface water.	Moderate		
Installation of water supply well may not occur under future industrial land use scenario.	Low		
Exposure parameters for current recreational land use may overestimate exposure.	Low		
Use of total body surface area for dermal exposure estimates.	Moderate		

* As a general guideline, assumptions marked as "low" may affect estimates of exposures by less than one order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between one and two orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than two orders of magnitude.

To evaluate noncarcinogenic effects of exposure, an RfD is the toxicity value most often used. An RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (USEPA 1989). Values for RfDs were obtained from the IRIS or the HEAST, both USEPA sources. In the absence of data from these sources, provisional values (if available) were obtained from Region VI USEPA risk assessment staff.

In deriving RfDs, uncertainty factors and modifying factors are applied to account for specific areas of uncertainty inherent in data. RfDs are eventually verified by an RfD workgroup. RfDs that appear on IRIS have been verified; RfDs in HEAST have not been verified.

To evaluate carcinogenic effects of exposure, a SF and a weight-of-evidence determination are the toxicity data most commonly used. Available data are evaluated to determine the likelihood that the agent is a human carcinogen. Both human studies and animal studies are evaluated and characterized as to carcinogenicity. Based on the evaluation, the chemical is given a <u>weight-of-evidence</u> classification ranging from human carcinogen to evidence of noncarcinogenicity for humans. This classification system is as follows:

Group A	Human carcinogen;
Group B1	Probable human carcinogen with limited human data;
Group B2	Probable human carcinogen with sufficient evidence in animals and inadequate or no evidence in humans;
Group C	Possible human carcinogen;
Group D	Not classifiable as to human carcinogenicity;
Group E	Evidence for noncarcinogenicity for humans.

The SF is the toxicity value that defines quantitatively the relationship between dose and response. Generally, the SF is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime (USEPA 1989). Slope factors should always be accompanied by weight-of-evidence classification. Slope factors and weights-of-evidence were obtained from either IRIS or HEAST. In the absence of data from these sources, provisional values (if available) were obtained from USEPA Region VI. Slope factors on IRIS have been verified by the Carcinogenic Risk Assessment Verification Endeavor (CRAVE) workgroup. Slope factors in HEAST have not been verified.

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In the following sections, the source of toxicity information for noncarcinogens and carcinogens associated with LHAAP Group 1 sites were IRIS and toxicological profiles for the various chemicals prepared by the Agency for Toxic Substances and Disease Registry.

2.4.2 Toxicological Information for Noncarcinogens.

Acetone. The primary route of exposure to acetone is dermal, although acetone can also be inhaled or ingested. Limited human studies have shown that workers exposed to acetone vapors (600 to 2,150 parts per million [ppm]) experienced transient eye and nose irritation. Animals exposed to acetone vapors at 45,134 mg/m^3 experienced slight but not significant decreases in organ and body weights.

The oral RfD for acetone is 1E-1 mg/Kg-day with an uncertainty factor of 1,000 and a modifying factor of 1. The critical effects are increased liver and kidney weights and nephrotoxicity and are based on a rat oral subchronic study. The overall confidence rating for the RfD is low based on the data base.

Antimony. Antimony is a silvery-white metal found in very low levels in the environment. Antimony can enter the body by inhalation of contaminated dust or ingestion of contaminated food, water, or dust. It is not known if antimony can enter the body through dermal absorption. A small amount of ingested antimony enters the blood after a few hours. Antimony in the lungs will enter the blood after several days or weeks. The amount of antimony that enters the blood from the lungs is not known.

Antimony can have beneficial effects when used for medical reasons and is sometimes used as a medicine for treatment of those infected with parasites. Exposure to antimony for extended periods can irritate the eyes, skin, and lungs, and can cause heart problems, vomiting, and diarrhea. It is not known if antimony can cause cancer or birth defects or affect reproduction in humans.

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The oral RfD for antimony is 4E-4 mg/Kg-day with an uncertainty factor of 1,000 and a modifying factor of 1. Confidence in the oral RfD is medium. Based on animal studies, the critical effects are longevity, blood glucose, and cholesterol. No data are available for an inhalation RfC. This information is available on IRIS.

Arsenic. Arsenic that enters the body through inhalation of contaminated particles is then rapidly absorbed through the lungs into the bloodstream. Most arsenic absorbed into the body is converted by the liver to a less toxic form that is efficiently excreted in the urine. Therefore, arsenic does not tend to accumulate in the body. Although large doses of inorganic arsenic may cause death, there is some evidence that low levels of exposure may be beneficial to human health.

Chronic toxicity of arsenic depends principally on chemical form, physical state, particle size, and solubility of material tested, with the trivalent form more toxic than the pentavalent form. Methylated forms appear to be less toxic. Critical effects on humans caused by oral exposure are hyperpigmentation, keratosis, and possible vascular complications. Chronic oral inhalation exposures in humans yield similar effects, the most common being skin lesions, peripheral vascular disease, and peripheral neuropathy.

The oral RfD for arsenic is 3E-4 mg/Kg-day with an uncertainty factor of 3 and a modifying factor of 1. Confidence in the oral RfD is medium. No data are available for an inhalation RfC. This information is available on IRIS.

Barium. Barium that enters the body through inhalation is absorbed into the bloodstream easily. However, barium does not enter the bloodstream very well from the stomach and intestine, so ingestion is not a normal pathway associated with health problems. It is very rare that barium enters through the skin. Most of the barium that enters the body is removed within a few days, mainly in feces or urine.

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Eating or drinking large amounts of barium for a short time may cause death or paralysis in a few individuals. Other effects on humans ingesting barium for a short time, either by water or food, include breathing difficulty; increased blood pressure; changes in heart rhythm; stomach irritation; minor changes in blood; muscle weakness; changes in nerve reflexes; swelling of the brain; and damage to the liver, heart, kidney, and spleen. No reliable information is available about the possible health effects in humans who are exposed to barium by breathing or by direct skin contact.

The oral RfD for barium is 7E-2 mg/Kg-day with an uncertainty factor of 3 and a modifying factor of 1. The critical effect as determined in human drinking water studies is increased blood pressure. Based on the data base and studies, the oral RfD is assigned a medium confidence. The inhalation RfC is under review but a provisional RfC of 1.43E-04 mg/m^3 was obtained from USEPA Region VI.

Benzo(a)pyrene. The general population may be exposed to dust, soil, and other particles that contain benzo(a)pyrene. The largest sources in the air are open burning and home heating with wood and coal. The most common exposure pathway for benzo(a)pyrene is through inhalation. It also may enter the body through ingestion. Benzo(a)pyrene does not usually enter the body through dermal contact. No information has been found about specific levels of benzo(a)pyrene that have caused harmful effects in people after breathing, swallowing, or touching the substance. Mice fed high levels during pregnancy had trouble reproducing, and so did their offspring. The newborn animals of pregnant mice fed benzo(a)pyrene also had birth defects and low body weight. Most research concerning health effects of this chemical have evaluated carcinogenic effects. An oral RfD has not been published in IRIS.

Benzoic Acid. Benzoic acid is a naturally-occurring chemical found in cranberries, prunes, and other natural sources. Benzoic acid is also manufactured for use as a food preservative or in pharmaceutical and cosmetic preparations. It may also be used in plasticizer manufacturing. Exposure to benzoic acid may occur during ingestion of food, water, or dust; inhalation of contaminated dust; or through dermal exposure.

019832

The oral RfD for benzoic acid is 4E+0 mg/Kg-day with an uncertainty factor of 1 and a modifying factor of 1. Confidence in the oral RfD is medium. No critical effects were reported.

Bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate is used primarily as a plasticizer in the production of plastics and in consumer products such as imitation leather, rainwear, footwear, upholstery, flooring, and children's toys. Humans are primarily exposed through foods that come into contact with packaging materials containing bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl) phthalate is quickly absorbed and metabolized once in the gastrointestinal tract. Humans may also receive higher exposure during blood transfusions and kidney dialysis because of the movement of blood from plastic bags and tubing. Information on human exposures to bis(2-ethylhexyl) phthalate and related health effects is not available. However, animals studies are available and short-term inhalation studies have indicated adverse health effects. Inhalation of bis(2-ethylhexyl) phthalate is only anticipated through exposure to fumes from heated or burning material. In short-term animal studies, death has resulted from ingestion of relatively high doses. In other animal studies, both short-term and long-term ingestion of bis(2-ethylhexyl)phthalate has resulted in liver toxicity, reproduction toxicity, and toxicity to the unborn or newborn.

The oral RfD for bis(2-ethylhexyl)phthalate is 2E-2 mg/Kg-day with an uncertainty factor of 1,000 and a modifying factor of 1. The critical effect was increased relative liver weight. Confidence in the oral RfD is medium.

2-Butanone. 2-Butanone, also known as methyl ethyl ketone, is a colorless liquid with a sweet, but sharp odor. This liquid will quickly evaporate into the air. 2-Butanone can enter the body through inhalation, dermal contact, and ingestion. Studies have shown that at least half of inhaled 2-butanone will be absorbed by the body. Elimination is through urine and respired air.

The main health effects observed in humans who breathed high concentrations of 019833
2-butanone are mild irritations of the nose, throat, eyes, and skin. Serious health effects in animals have been seen only at very high concentrations. Studies in animals have shown that 2-butanone does not cause serious damage to the nervous system, the kidney, or the liver, but baboons and mice that breathed low levels for a short time had behavioral effects.

The oral RfD for 2-butanone is 6E-1 mg/Kg-day with an uncertainty factor of 3,000 and a modifying factor of 1. Confidence in the oral RfD is low. The inhalation RfC is 1E+0 mg/m^3 with an uncertainty factor of 1,000 and a modifying factor of 3. Confidence in the inhalation RfC is low.

Cadmium. Food and cigarette smoke are the largest potential sources of cadmium exposure for the general population. Very little cadmium enters through the skin. Cadmium is poorly absorbed (4.6 to 6%) following oral administration in humans, although the percent may be altered by a variety of dietary parameters. Factors shown to increase cadmium absorption include low intake of dietary calcium, Vitamin D, protein, zinc, iron, copper, and ascorbic acid. The body rapidly takes in about one-fourth of the cadmium inhaled and about 5% of cadmium in food or water. Cadmium that enters the body goes to the liver and kidney, and very little leaves the body. Under normal conditions, the body stores cadmium in a safe form, but too much can cause adverse health effects.

The oral RfD for cadmium is 5E-4 mg/Kg-day for ingestion by water and 1E-3 mg/Kg-day for ingestion by food, both with uncertainty factors of 10 and modifying factors of 1. The RfDs are based on human studies involving chronic exposures at which the critical effect was significant proteinuria. Because of high confidence in the data base, both RfDs have high confidence levels. The inhalation RfC is under review by an EPA workgroup.

Chromium VI. Chromium exposure can occur by inhalation, ingestion of water and food, and skin contact. Once inside the body, chromium VI is normally changed to chromium III, which is a necessary part of the diet. Most of the ingested chromium leaves the body within a few days and never enters the blood. A small amount (about 0.4 to 2.1%) passes through the kidneys and is eliminated in the urine in a few days. Dermal absorption of chromium from water or the atmosphere appears to be very low.

The oral RfD for chromium VI is 5E-3 mg/Kg-day with an uncertainty factor of 500 and a modifying factor of 1. In a one-year drinking water study of rats, no effects were reported at an experimental dose of 25 mg/l of chromium as potassium chromate. This level is reported as the no-observed-adverse-effects-level. Confidence in this study is low so confidence in the RfD is low. The inhalation RfC is under review by an EPA workgroup.

Isophorone. Isophorone is a clear liquid with a peppermint-like odor that evaporates very quickly into air. Isophorone does not remain in the air long but can remain in water and soil for possibly more than 20 days.

Isophorone can enter the body through inhalation, dermal contact, and ingestion. Experiments in animals show that after doses by mouth, isophorone enters easily and spreads to many organs of the body, but most of it leaves the body within 24 hours in the breath and in urine. How much isophorone enters the body through the skin is not known. The only effects of isophorone reported in humans are irritation of the skin, eyes, nose and throat, and possibly dizziness and fatigue.

The oral RfD for isophorone is 2E-1 mg/Kg-day with an uncertainty factor of 1,000 and a modifying factor of 1. No critical effects were reported. The confidence level in the RfD is low. Data for the RfC was determined to be inadequate by the EPA RfD/RfC workgroup.

Lead. Humans are commonly exposed to lead through inhalation and ingestion while absorption of lead through the skin is not a significant method of human exposure. Regardless of how lead enters the body, most of it is stored in bone. This is a cumulative process that results in increasing levels of lead in bone and teeth with age.

Lead is a unique chemical in its pharmacokinetic and toxicological properties. Although it is classified as both a noncarcinogen and potential carcinogen (B2 weight of evidence), it is most often assessed as a noncarcinogen only, as these effects manifest themselves at doses lower than those for carcinogenicity. In contrast to other noncarcinogens, the assumption of a threshold below which there is no response does not appear to hold true for lead. For these reasons, blood lead levels are often evaluated rather than chronic daily intakes. These evaluations are often conducted using the USEPA "Integrated Exposure Uptake and Biokinetic" (IEUBK) model. This model addressees impacts on children from birth to seven years of age but does not assess lead effects on older children or adults. As such, there is currently no generally accepted method for assessing potential impacts of lead exposure to adult receptors. As children were not an identified exposed population for this assessment, lead evaluations using the IEUBK model were not performed.

As a result of the above considerations, toxicological values (RfD, RfC, SF) are not currently considered appropriate for evaluations of lead exposure and have not been proposed by the USEPA. However, a screening level of 2,000 ppm lead concentration in soils is currently considered acceptable by EPA for non-residential adult exposure (Bowers et al. 1994, EPA 1996).

Mercury. Mercury is a chemical that occurs naturally in the environment in several forms. Mercury can easily enter the body if its vapor is breathed in or if it is eaten in organic forms in contaminated water or food (most likely fish). Mercury, in all forms, may also enter the body directly through the skin. Once mercury has entered the body, it may persist for months. It leaves the body mostly through the urine and feces. Long-term exposure to either organic or inorganic mercury can permanently damage the brain, kidneys, and developing fetuses. Short-term exposure to high levels of inorganic and organic mercury will have similar health effects, but full recovery is more likely than for long-term exposures.

An RfD on IRIS is not available for mercury. A provisional value of 3E-4 mg/Kg-day was obtained from USEPA Region VI. The inhalation RfC is 3E-4 mg/m^3 with a modifying factor of 30. The critical effect was hand tremors and increases in memory disturbances.

Nickel. Humans can be exposed to nickel by inhalation, ingestion of food and water, and dermal exposure. After nickel enters the body, most of it goes to the kidneys. After inhalation of nickel, some leaves the body quickly in the feces and some stays in the lungs. Nickel that gets into the bloodstream leaves in the urine. After nickel is ingested, almost all of it leaves quickly in the feces, and the small amount that gets into the body leaves in the urine. Nickel is known to be a contact irritant, but many studies have also demonstrated dermal effects in sensitive humans resulting from ingested nickel. Indications are that ingested nickel may invoke an eruption or worsening of eczema.

The oral RfD for nickel is 2E-2 mg/Kg-day with an uncertainty factor of 300 and a modifying factor of 1. The critical effects of decreased body and organ weights were determined with a chronic oral study using rats. The oral RfD has a medium confidence level. The inhalation RfC is under review by an EPA workgroup.

Methylene Chloride. Methylene chloride is a colorless liquid that has a mild, sweet odor; evaporates rapidly; and will not burn easily. It is widely used as an industrial solvent and paint stripper. The greatest potential for exposure is by inhalation. When inhaled, about 70% enters the bloodstream and spreads to various organs. Some of it is broken down into other chemicals. Unchanged methylene chloride and its breakdown products are usually removed in the breath within 48 hours after exposure. Small amounts leave in the urine. The rate of uptake through the skin and stomach have not been measured.

The oral RfD for methylene chloride is 6E-2 mg/Kg-day with an uncertainty factor of 100 and a modifying factor of 1. The critical effect was liver toxicity based on a 2-year rat drinking water bioassay. The confidence level in the RfD is medium because of the data base. The inhalation RfC is under review by an EPA workgroup, but a provisional value of 8.57E-1 mg/m^3 was obtained from USEPA Region VI risk assessment staff.

Polycyclic Aromatic Hydrocarbon Compounds. Polycyclic aromatic hydrocarbons are a class of compounds containing hydrogen and oxygen in multiple-ring structures. There are a number of possible PAH compounds, many of which are included in semivolatiles analyses. Polycyclic aromatic hydrocarbons are a natural component of petroleum and are also produced by incomplete combustion of organic matter. They are created during fires, volcanoes, combustion of motor fuels and oil, etc. Accordingly, PAHs are ubiquitous in the environment at low levels, particularly in soil and sediment. Humans may be exposed to PAHs from the air, water, soil, cigarette smoke, and cooked food. Cooking food at high temperatures, as occurs during charcoal-grilling or charring, can increase the amount of PAH intake. Polycyclic aromatic hydrocarbons usually enter the body through inhalation and ingestion.

Most toxicological work with PAHs has been associated with carcinogenic effects. Oral RfDs and RfCs have not been developed for individual PAH compounds.

Selenium. Selenium is a naturally-occurring element that is widely but unevenly distributed in the earth's crust. It is commonly found in sedimentary rock. The human body easily absorbs organic selenium compounds that are ingested. Selenium can build up in the human body, mostly in the liver and kidneys and, to a lesser extent, in the blood, lungs, heart, and testes. Selenium leaves the body mainly in the urine, and less in feces and breath. Studies of human population do not show that common selenium compounds caused cancer in humans. Although exposure to high levels of inorganic selenium compounds has been shown to cause birth defect in birds, selenium compounds have not been shown to cause birth defects in humans or other mammals.

The oral RfD is 5E-3 mg/Kg-day with an uncertainty factor of 3 and a modifying factor of 1. The critical effect was clinical selenosis. The oral RfD has a confidence level of high. The inhalation RfC is not available.

Silver. Silver is a rare, but naturally-occurring element in the environment. Silver may enter the body through ingestion of water, food, or medicines. Silver can enter the body through the skin when put into powders or solutions containing silver compounds, such as those used in photography. Most of the silver that is eaten or inhaled leaves the body in the feces within about a week. Very little passes through the urine. The silver remaining within the body may build up in a variety of places. It is not known how much dermally-absorbed silver leaves the body.

Ingestion or inhalation of silver over a long period (several month to many years) can cause some areas of the skin and other body tissues to turn gray or blue-gray. This condition is call argyria. Once an individual has argyria, it is permanent but is considered to be only a "cosmetic" problem. Most doctors and scientists believe that the discoloration of the skin seen in argyria is the most serious health effect of silver. Exposure to dust containing relatively high levels of silver compounds, such as silver nitrate or silver oxide, may cause breathing problem, lung and throat irritation, and stomach pain. One animal study suggests that long-term exposure to moderately high levels of silver nitrate in drinking water may have a slight effect on the brain.

The oral RfD for silver is 5E-3 mg/Kg-day with an uncertainty factor of 3 and a modifying factor of 1. The critical effect was argyria. The oral RfD has a confidence level of low. The inhalation RfC is not available.

Thallium. Pure thallium is a soft, bluish-white metal that is widely distributed in trace amounts in the earth's crust. Thallium can enter the body through inhalation, ingestion, or dermal contact. When thallium is swallowed, most of it is absorbed and rapidly goes to various parts of the body, especially the kidney and liver. Thallium leave the body slowly. Most leaves the body in urine and to a lesser extent in feces. Thallium can affect the nervous system, lung, heart, liver, and kidney if large amounts are ingested for short periods of time. Temporary hair loss, vomiting, and diarrhea can also occur, and death may result after exposure to large amounts for short periods. No information was found on health effects in humans after exposure to smaller amounts of thallium for longer periods.

The oral RfD for this substance has been withdrawn pending further review by the RfD/RfC workgroup. The inhalation RfC is not available.

Toluene. Toluene is a clear, colorless liquid with a sweet smell that occurs naturally in crude oil. It is produced from petroleum refining processes and used in refining gasoline, chemical manufacturing, and manufacture of other products. It is usually disposed of as a used solvent and readily breaks down in soil and evaporates from water.

Inhalation is the most common method of human exposure to toluene but it may also be ingested with contaminated food or water. Most toluene leaves the body within 12 hours unchanged in exhaled air. It also leaves the body as a breakdown product in urine. The most important health concern for humans is its harmful effects on the nervous system. These symptoms normally disappear when exposure ceases.

The oral RfD for toluene is 2E-1 mg/Kg-day with an uncertainty factor of 1,000 and a modifying factor of 1. The critical effects are changes in liver and kidney weights determined by a 13-week gavage study with rats. The confidence level for the RfD is medium.

The inhalation RfC is 4E-1 mg/m^3 with an uncertainty factor of 300 and a modifying factor of 1. The critical effect is neurological effects based on an occupational study of female workers at an electronic assembly plant where toluene was emitted from glue. The confidence level for the RfC is medium.

Xylene. Xylene is a colorless liquid with a sweet odor. It is primarily man-made but also occurs naturally in petroleum and coal tar and is formed during forest fires. Xylene evaporates and burns easily. It does not mix well with water but will mix with other organic chemicals. If it leaks into surface water, soil, or groundwater, it can remain for six months or longer before it breaks down into other chemicals. It can also remain in air for several days before it is broken down by sunlight.

Inhalation is the most common pathway by which xylene enters the human body, but it can also be absorbed through the skin if direct contact occurs. Exposure is also possible by ingesting contaminated food or drinking water. Soon after entering the body, xylene passes into the blood. Most of the xylene in the body is broken down into other chemicals. After breakdown, xylene products quickly leave the body, mostly in urine, but with some unchanged xylene in the breath.

The oral RfD for xylene is 2E+0 mg/Kg-day with an uncertainty factor of 100 and a modifying factor of 1. The critical effects are hyperactivity, decreased body weight, and increased mortality in males based on a chronic rat gavage study. The confidence level for the RfD is medium.

The inhalation RfC for xylene is under review by an EPA workgroup. A provisional RfC of 2E-1 mg/m^3 was obtained from USEPA Region VI.

2.4.3 Toxicity Information for Carcinogenic Effects. USEPA's CRAVE workgroup has developed SFs (dose-response values) for estimated lifetime excess cancer risk associated with exposure to a potential carcinogen. Risks estimated using SFs are considered unlikely to underestimate actual risks, but may overestimate actual risks. Excess lifetime cancer risks are generally expressed in scientific notation as probabilities. An excess lifetime cancer risk of 1E-6 (one in 1,000,000), for example, represents the probability that one individual in a population of one million will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specific exposure conditions. The USEPA has suggested developing remedial

alternatives for cleanup of Superfund sites using total excess lifetime cancer risk ranging from 019841
1E-4 (one in 10,000) to 1E-6 (one in 1,000,000).

Arsenic. Arsenic is classified as a Group A human carcinogen by the USEPA. This means there is sufficient evidence of carcinogenicity in humans. This classification is based on observations of increased lung cancer mortality in populations exposed primarily through inhalation and on increased cancer incidence in several populations consuming drinking water with high arsenic concentrations.

The oral SF for arsenic is 1.5E+0 mg/Kg-day. While an inhalation unit risk of 4.3E-3 ug/m^3 is present on IRIS, an inhalation SF of 5E+1 per mg/Kg-day is available in HEAST. Due to development of this value as an actual SF, this value was used for this assessment.

Benzo(a)pyrene. Benzo(a)pyrene, a PAH, is classified as a Group B2 carcinogen (probable human carcinogen) by the USEPA. Human data specifically linking benzo(a)pyrene to a carcinogenic effect is lacking, but there are multiple animal studies demonstrating benzo(a)pyrene to be carcinogenic. Benzo(a)pyrene causes cancer in laboratory animals when applied to their skin. No information has been found about specific levels of benzo(a)pyrene that have caused harmful effects in humans.

The oral SF for benzo(a)pyrene is 7.3+0 mg/Kg-day. An inhalation SF of 6.1 per mg/Kg-day was provided by USEPA Region VI.

Cadmium. Cadmium is classified as a Group B1 carcinogen (probable human carcinogen by inhalation) by the USEPA. This classification is based on limited evidence from studies of occupationally exposed workers. In addition, there is sufficient evidence of carcinogenicity in rats and mice by inhalation and intramuscular and subcutaneous injection. The inhalation risk unit is 1.8E-3 per ug/m^3.

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Studies of rats and mice where cadmium salts were administered orally have shown no evidence of carcinogenic response. Studies of human ingestion of cadmium are inadequate to assess carcinogenicity. As a result, cadmium is currently recognized as carcinogenic by the inhalation route of exposure only.

Chromium VI. Chromium VI is classified as a Group A carcinogen (human carcinogen by inhalation) by the USEPA. This classification is based on results of occupational studies of chromium-exposed workers. In addition, only chromium VI was found to be carcinogenic in animal studies; therefore, it was concluded that only chromium VI should be classified as a human carcinogen. A dose-response relationship for lung tumors has been established. Trivalent chromium compounds have not been reported as carcinogenic by any route of administration. While an inhalation risk unit for chromium VI of 1.2E-2 per ug/m^3 is available on IRIS, an inhalation SF of 4.1E+1 per mg/Kg-day is provided in HEAST. As this value is a developed SF, it was used in this assessment.

Isophorone. Isophorone is currently classified as a Group C carcinogen (possible human carcinogen). The oral SF is 9.5E-4 per mg/Kg-day.

Lead. Lead is classified by the USEPA as a Group B2 carcinogen (probable human carcinogen) which means that there is sufficient evidence of carcinogenicity in animals but inadequate or lack of evidence in humans. Animal assays have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts.

There is no SF. Because quantifying lead's cancer risk involves many uncertainties, some of which may be unique, it was recommended by an EPA workgroup that a numerical estimate not be used. These considerations for lead are summarized in the preceding section of this report under "noncarcinogenic effects".

Methylene Chloride. Methylene chloride is classified as a Group B2 carcinogen (probable human carcinogen) by the USEPA for both oral and inhalation routes of exposure. This classification is based on evidence of carcinogenicity in animals caused by inhalation and ingestion of methylene chloride. The oral SF is 7.5E-3 per mg/Kg-day, and the inhalation risk unit is 4.7E-7 per ug/m^3.

Polycyclic Aromatic Hydrocarbon Compounds. Many PAH compounds are classified as a Group B2 carcinogen (probable human carcinogen) by the USEPA. In the past, USEPA quantitative risk estimates for mixtures of PAHs have often assumed that all carcinogenic PAHs are equipotent to benzo(a)pyrene and that the carcinogenic effect of the mixture can be estimated by the sum of the effect of each individual PAH. Currently, the USEPA has published comparative risk estimates for assessment of potentially carcinogenic PAHs as temporary guidance while research on relative potencies for PAHs is ongoing. These estimates were used in this assessment and are described below.

Toxicity values for carcinogenic PAHs were estimated using a toxicity equivalency factor (TEF) relative to benzo(a)pyrene as presented in USEPA (1993b). This approach is also recommended in the Region VI supplemental risk assessment guidance. Oral and inhalation SFs for individual PAHs were derived by multiplying those for benzo(a)pyrene (presented above) by the following TEFs:

Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenzo(a,h)anthracene	1.0
Ideno(1,2,3-cd)pyrene	0.1

2.4.4 Uncertainties Related to Toxicity Information. Toxicity information for this risk assessment was gathered from three primary sources: IRIS, HEAST, and USEPA Region VI risk assessment staff.

Reference doses and reference concentrations in HEAST are provisional estimates with uncertainties sometimes spanning an order of magnitude. Uncertainty factors and modifying factors are applied to account for specific areas of uncertainty inherent in data. Values taken from HEAST have not been verified by an EPA workgroup and are subject to change pending review. In instances where an RfD or an RfC has been determined from another exposure route or through route-to-route extrapolation, some degree of uncertainty is introduced. Uncertainty is likewise associated with the use of provisional toxicity values.

The SF is an upper-bound estimate of the true risk to human health and may be higher or lower than the true risk. Slope factors and inhalation unit risk factors include weight-of-evidence classifications which are an indication of inherent uncertainty.

Numerous assumptions and extrapolations are required in toxicological studies, and evaluation of these studies may require interpretation of conflicting results. Slope factors, inhalation unit risk factors, RfCs, and RfDs used in this assessment include uncertainty factors recognized by the USEPA.

2.5 RISK CHARACTERIZATION

2.5.1 General. The final step of the risk assessment process is risk characterization. This process involves integration of exposure assessment results and toxicity information in quantitative estimates of risk to human health. Quantified potential risk estimates are segregated by values representing both carcinogenic and noncarcinogenic health effects and are initially developed for individual chemicals via specific exposure routes. Next, risk estimates for individual chemicals (carcinogenic and noncarcinogenic) for each exposure pathway are summed to obtain total pathway risk. Finally, total pathway risks are summed, when appropriately representing total receptor exposure, to yield an estimate of total site risk for carcinogenic as well as noncarcinogenic effects. For this risk assessment, these procedures were used for risk characterization for both RME and CTE under current and future land use scenarios.

For carcinogens, "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk)" (USEPA 1989). Risk estimates are obtained by multiplying daily intakes by published or calculated SFs. A maximum target risk range of 10^{-4} to 10^{-6} serves as a Superfund site remediation goal under the National Contingency Plan (USEPA 1989) and has generally been acknowledged as representative of acceptable risk.

Noncarcinogenic risk estimates are obtained by calculation of a non-cancer hazard quotient. The hazard quotient assumes that there is a level of exposure below which it is unlikely that even sensitive subpopulations will experience adverse health effects. If the exposure exceeds this threshold, there may be concern for potential non-cancer health effects (USEPA 1989).

Chemical-specific hazard quotients are calculated by dividing intakes by published RfDs for oral routes of exposure, or by use of calculated inhalation RfDs (explained in Chapter 1) for inhalation exposure. As in carcinogenic risk estimation, hazard quotients are then summed for individual pathways and a hazard index (HI) obtained. Finally, estimates of total non-cancer site risks are obtained by summing total HIs for all appropriate exposure pathways. Final HIs (as well as chemical or pathway-specific indices) in excess of unity (1.0) are an indication of possible non-cancer health concerns associated with the site.

Quantification of risks are frequently hindered by a lack of toxicological data for some site chemicals. This lack of data should always be considered in site-related decisions based on quantified risk estimation results.

Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios at LHAAP Site 1 are all presented below.

2.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at Site 1 are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

2.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates derived for current recreational land use are presented in Tables 2-9 and 2-10 for RME and CTE, respectively. Evaluation of these estimates reveal that non-cancer risks are dominated by exposure to metals (principally chromium) via dermal contact with site soils (pathway HI = 2E-2 and 3E-3 for RME and CTE, respectively) and, to a lesser degree, dermal contact with surface waters. Volatile organic compounds detected at the site contribute little to overall non-cancer risks for all exposure pathways. Total exposure hazard indices of 4E-2 and 2E-2 (RME and CTE, respectively) are extremely low, well-below unity, and are not indicative of non-cancer health concerns for current land use at LHAAP Site 1. A lack of toxicological data for non-cancer health effects associated with PAHs at the site lends a degree of uncertainty to these estimates, and should be considered in interpretation of these results.

2.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 2-11 and 2-12 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to PAHs (principally benzo(a)pyrene) via dermal contact with site soils. Total exposure risk estimates of 1E-6 and 5E-7 (RME and CTE, respectively) are well within the acceptable carcinogenic risk range and do not indicate a concern for cancer-related health effects for current site land use practices. With the exception of lead, toxicity values were available for all evaluated carcinogens, lending increased confidence to these estimates.

Table 2-9. Hazard Index Estimates, Site 1, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Acetone	1.19E-7	1E-1	Organ weights	IRIS	1,000	1	1.2E-6		
Methylene Chloride	4.70E-9	6E-2	Liver toxicity	IRIS	100	1	7.8E-8		
Toluene	3.53E-9	2E-1	Organ weights	IRIS	1,000	1	1.8E-8		
Xylene	3.53E-9	2E+0	Hyperactivity	IRIS	100	1	1.8E-9		
2-Butanone	2.70E-8	6E-1	Decr. birth weight	IRIS	3,000	1	4.5E-8		
Benzoic Acid	2.50E-6	4E+0	None given	IRIS	1	1	6.3E-7		
Phenanthrene	3.05E-7	Under Review							
Fluoranthene	3.73E-7	4E-2	Nephropathy	IRIS	3,000	1	9.3E-6		
Pyrene	3.50E-7	3E-2	Kidney effects	IRIS	3,000	1	1.2E-5		
Benzo(a)anthracene	2.68E-7								
Chrysene	2.43E-7								
Bis(2-ethylhexyl)phthalate	3.10E-7	2E-2	Incr. liver weight	IRIS	1,000	1	1.6E-5		
Benzo(k)flouranthene	2.83E-7								
Benzo(b)flouranthene	2.75E-7								
Benzo(a)pyrene	2.75E-7								
Ideno(1,2,3-cd)pyrene	2.45E-7								
Dibenzo(a,h)anthracene	6.93E-8								
Benzo(g,h,i)perylene	2.39E-7								
Antimony	6.58E-8	2E-5	Longevity	IRIS	1,000	1	3.3E-3		
Arsenic	5.03E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.7E-3		
Barium	7.93E-6	3.5E-3	Incr. blood press.	IRIS	3	1	2.3E-3		
Cadmium	6.10E-8	3E-4	Proteinuria	IRIS	10	1	2.0E-4		
Chromium	1.75E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Lead	2.01E-6	Inappropriate For Evaluation							
Mercury	9.40E-9	1.5E-5	Hand tremor	EPA Reg. VI			6.3E-4		
Nickel	8.28E-7	1.0E-3	Decreased weight	IRIS	300	1	8.3E-4		
Selenium	4.93E-8	2.5E-4	Selenosis	IRIS	3	1	2.0E-4		
Silver	1.13E-7	2.5E-4	Argyria	IRIS	3	1	4.5E-4		
								2E-2	

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Table 2-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Acetone	2.36E-8	1E-1	Organ weights	IRIS	1,000	1	2.4E-7		
Methylene Chloride	9.36E-10	6E-2	Liver toxicity	IRIS	100	1	1.6E-8		
Toluene	7.02E-10	2E-1	Organ weights	IRIS	1,000	1	3.5E-9		
Xylene	7.02E-10	2E+0	Hyperactivity	IRIS	100	1	3.5E-10		
2-Butanone	5.38E-9	6E-1	Decr. birth weight	IRIS	3,000	1	9.0E-9		
Benzoic Acid	2.60E-7	4E+0	None given	IRIS	1	1	6.5E-8		
Phenanthrene	6.06E-8	Under Review							
Fluoranthene	7.44E-8	4E-2	Nephropathy	IRIS	3,000	1	1.9E-6		
Pyrene	6.95E-8	3E-2	Kidney effects	IRIS	3,000	1	2.3E-6		
Benzo(a)anthracene	5.31E-8								
Chrysene	4.84E-8								
Bis(2-ethylhexyl)phthalate	6.15E-8	2E-2	Incr. liver weight	IRIS	1,000	1	3.1E-6		
Benzo(k)flouranthene	5.64E-8								
Benzo(b)flouranthene	5.45E-8								
Benzo(a)pyrene	5.48E-8								
Ideno(1,2,3-cd)pyrene	4.87E-8								
Dibenzo(a,h)anthracene	1.38E-8								
Benzo(g,h,i)perylene	4.75E-8								
Antimony	1.31E-7	4E-4	Longevity	IRIS	1,000	1	3.3E-4		
Arsenic	1.00E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.3E-3		
Barium	1.58E-5	7E-2	Incr. blood press.	IRIS	3	1	2.3E-4		
Cadmium	1.22E-7	1E-3	Proteinuria	IRIS	10	1	1.2E-4		
Chromium	3.48E-6	5E-3[3]	None given	IRIS	500	1	7.0E-4		
Lead	4.01E-6	Inappropriate For Evaluation							
Mercury	1.87E-8	3E-4	Hand tremor	EPA Region VI			6.2E-5		
Nickel	1.65E-6	2E-2	Decreased weight	IRIS	300	1	8.3E-5		
Selenium	9.83E-8	5E-3	Selenosis	IRIS	3	1	2.0E-5		
Silver	2.25E-7	5E-3	Argyria	IRIS	3	1	4.5E-5		
								5E-3	

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Table 2-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Benzoic Acid	3.01E-11								
Phenanthrene	7.02E-12								
Fluoranthene	8.62E-12								
Pyrene	8.05E-12								
Benzo(a)anthracene	6.15E-12								
Chrysene	5.61E-12								
Bis(2-ethylhexyl)phthalate	7.13E-12								
Benzo(k)flouranthene	6.53E-12								
Benzo(b)flouranthene	6.13E-12								
Benzo(a)pyrene	6.34E-12								
Ideno(1,2,3-cd)pyrene	5.64E-12								
Dibenzo(a,h)anthracene	1.60E-12								
Benzo(g,h,i)perylene	5.50E-12								
Antimony	1.52E-11								
Arsenic	1.16E-10								
Barium	1.83E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			4.5E-5		
Cadmium	1.41E-11								
Chromium	4.03E-10								
Lead	4.64E-10								
Mercury	2.17E-12	8.58E-5	Hand tremor	EPA Reg. VI			2.5E-8		
Nickel	1.19E-10								
Selenium	1.14E-11								
Silver	2.60E-11								
								5E-5	

Table 2-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Acetone	4.47E-7								
Methylene Chloride	4.86E-8	2.45E-1	Liver toxicity	EPA Reg. VI			2.0E-7		
Toluene	1.85E-8	1.14E-1	Organ weight	IRIS	300	1	1.6E-7		
Xylene	2.24E-8	5.72E-2	Hyperactivity	EPA Reg. VI			3.9E-7		
2-Butanone	1.21E-7	2.86E-1	Decr. birth wt.	IRIS	1,000	1	4.2E-7		
								1E-6	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1]									
Toluene	1.0E-5	2E-1	Organ weights	IRIS	1,000	1	5.0E-5		
Arsenic	3.22E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.1E-3		
Barium	1.00E-5	3.5E-3	Incr. blood press.	IRIS	3	1	2.9E-3		
Chromium	9.65E-7	2.5E-4[3]	None given	IRIS	500	1	3.9E-3		
Lead	2.90E-9	Inappropriate For Evaluation							
Nickel	3.21E-7	1.0E-3	Decreased weight	IRIS	300	1	3.2E-4		
								1E-2	
									4E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Value for chromium VI.

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Table 2-10. Hazard Index Estimates, Site 1, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Acetone	2.37E-8	1E-1	Organ weights	IRIS	1,000	1	2.4E-7		
Methylene Chloride	9.40E-10	6E-2	Liver toxicity	IRIS	100	1	1.6E-8		
Toluene	7.05E-10	2E-1	Organ weights	IRIS	1,000	1	3.5E-9		
Xylene	7.05E-10	2E+0	Hyperactivity	IRIS	100	1	3.5E-10		
2-Butanone	5.40E-9	6E-1	Decr. birth weight	IRIS	3,000	1	9.0E-9		
Benzoic Acid	2.60E-7	4E+0	None given	IRIS	1	1	6.5E-8		
Phenanthrene	6.08E-8	Under Review							
Fluoranthene	7.48E-8	4E-2	Nephropathy	IRIS	3,000	1	1.9E-6		
Pyrene	6.98E-8	3E-2	Kidney effects	IRIS	3,000	1	2.3E-6		
Benzo(a)anthracene	5.33E-8								
Chrysene	4.58E-8								
Bis(2-ethylhexyl)phthalate	6.18E-8	2E-2	Incr. liver weight	IRIS	1,000	1	3.0E-6		
Benzo(k)flouranthene	5.65E-8								
Benzo(b)flouranthene	5.48E-8								
Benzo(a)pyrene	5.50E-8								
Ideno(1,2,3-cd)pyrene	4.88E-8								
Dibenzo(a,h)anthracene	1.39E-8								
Benzo(g,h,i)perylene	4.78E-8								
Antimony	1.32E-8	2E-5	Longevity	IRIS	1,000	1	6.6E-4		
Arsenic	1.01E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.4E-4		
Barium	1.58E-6	3.5E-3	Incr. blood press.	IRIS	3	1	4.5E-4		
Cadmium	1.22E-8	3E-4	Proteinuria	IRIS	10	1	4.1E-5		
Chromium	3.50E-7	2.5E-4	None given	IRIS	500	1	1.4E-3		
Lead	4.03E-7	Inappropriate For Evaluation							
Mercury	1.88E-9	1.5E-5	Hand tremor	EPA Reg. VI			1.3E-4		
Nickel	1.65E-7	1.0E-3	Decreased weight	IRIS	300	1	1.7E-4		
Selenium	9.85E-9	2.5E-4	Selenosis	IRIS	3	1	3.9E-5		
Silver	2.25E-8	2.5E-4	Argyria	IRIS	3	1	9.0E-5		
								3E-3	

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Table 2-10 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Acetone	2.36E-8	1E-1	Organ weights	IRIS	1,000	1	2.4E-7		
Methylene Chloride	9.36E-10	6E-2	Liver toxicity	IRIS	100	1	1.6E-8		
Toluene	7.02E-10	2E-1	Organ weights	IRIS	1,000	1	3.5E-9		
Xylene	7.02E-10	2E+0	Hyperactivity	IRIS	100	1	3.5E-10		
2-Butanone	5.38E-9	6E-1	Decr. birth weight	IRIS	3,000	1	9.0E-9		
Benzoic Acid	2.60E-7	4E+0	None given	IRIS	1	1	6.5E-8		
Phenanthrene	6.06E-8	Under Review							
Fluoranthene	7.44E-8	4E-2	Nephropathy	IRIS	3,000	1	1.9E-6		
Pyrene	6.95E-8	3E-2	Kidney effects	IRIS	3,000	1	2.3E-6		
Benzo(a)anthracene	5.31E-8								
Chrysene	4.84E-8								
Bis(2-ethylhexyl)phthalate	6.15E-8	2E-2	Incr. liver weight	IRIS	1,000	1	3.1E-6		
Benzo(k)flouranthene	5.64E-8								
Benzo(b)flouranthene	5.45E-8								
Benzo(a)pyrene	5.48E-8								
Ideno(1,2,3-cd)pyrene	4.87E-8								
Dibenzo(a,h)anthracene	1.38E-8								
Benzo(g,h,i)perylene	4.75E-8								
Antimony	1.31E-7	4E-4	Longevity	IRIS	1,000	1	3.3E-4		
Arsenic	1.00E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.3E-3		
Barium	1.58E-5	7E-2	Incr. blood press.	IRIS	3	1	2.3E-4		
Cadmium	1.22E-7	1E-3	Proteinuria	IRIS	10	1	1.2E-4		
Chromium	3.48E-6	5E-3[3]	None given	IRIS	500	1	7.0E-4		
Lead	4.01E-6	Inappropriate For Evaluation							
Mercury	1.87E-8	3E-4	Hand tremor	EPA Reg. VI			6.2E-5		
Nickel	1.65E-6	2E-2	Decreased weight	IRIS	300	1	8.3E-5		
Selenium	9.83E-8	5E-3	Selenosis	IRIS	3	1	2.0E-5		
Silver	2.25E-7	5E-3	Argyria	IRIS	3	1	4.5E-5	5E-3	

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Table 2-10 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Benzoic Acid	3.01E-11								
Phenanthrene	7.02E-12								
Fluoranthene	8.62E-12								
Pyrene	8.05E-12								
Benzo(a)anthracene	6.15E-12								
Chrysene	5.61E-12								
Bis(2-ethylhexyl)phthalate	7.13E-12								
Benzo(k)flouranthene	6.53E-12								
Benzo(b)flouranthene	6.13E-12								
Benzo(a)pyrene	6.34E-12								
Ideno(1,2,3-cd)pyrene	5.64E-12								
Dibenzo(a,h)anthracene	1.60E-12								
Benzo(g,h,i)perylene	5.50E-12								
Antimony	1.52E-11								
Arsenic	1.16E-10								
Barium	1.83E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			4.5E-5		
Cadmium	1.41E-11								
Chromium	4.03E-10								
Lead	4.64E-10								
Mercury	2.17E-12	8.58E-5	Hand tremor	EPA Reg. VI			2.5E-8		
Nickel	1.19E-10								
Selenium	1.14E-11								
Silver	2.60E-11								
								5E-5	

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Table 2-10 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Acetone	4.47E-7								
Methylene Chloride	4.86E-8	2.45E-1	Liver toxicity	EPA Reg. VI			2.0E-7		
Toluene	1.85E-8	1.14E-1	Organ weight	IRIS	300	1	1.6E-7		
Xylene	2.24E-8	5.72E-2	Hyperactivity	EPA Reg. VI			3.9E-7		
2-Butanone	1.21E-7	2.86E-1	Decr. birth wt	IRIS	1,000	1	4.2E-7		
								1E-6	
Exposure Pathway: Dermal Contact with Surface Waters (Wading)[1]									
Toluene	1.0E-5	2E-1	Organ weights	IRIS	1,000	1	5.0E-5		
Arsenic	3.22E-7	3E-4	Hyperpigmentation	IRIS	3	1	1.1E-3		
			Vascular problems	IRIS					
Barium	1.00E-5	3.5E-3	Incr. blood press.	IRIS	3	1	2.9E-3		
Chromium	9.65E-7	2.5E-4[3]	None given	IRIS	500	1	3.8E-3		
Lead	2.90E-9	Inappropriate For Evaluation							
Nickel	3.21E-7	1.0E-3	Decreased weight	IRIS	300	1	3.2E-4		
								1E-2	
									2E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 2-11. Cancer Risk Estimates, Site 1, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	6.70E-10	7.5E-3	B2	Liver	IRIS	5.0E-12		
Benzo(a)anthracene	3.80E-8	7.3E-1	B2	Various	TEF*	2.8E-8		
Chrysene	3.48E-8	7.3E-3	B2	Various	TEF	2.5E-10		
Bis(2-ethylhexyl)phthalate	4.40E-8	1.4E-2	B2.	Liver	IRIS	6.2E-10		
Benzo(k)flouranthene	4.05E-8	7.3E-2	B2	Various	TEF	3.0E-9		
Benzo(b)flouranthene	3.90E-8	7.3E-1	B2	Various	TEF	2.9E-8		
Benzo(a)pyrene	3.93E-8	7.3E+0	B2	Forestomach	IRIS	2.9E-7		
Ideno(1,2,3-cd)pyrene	3.50E-8	7.3E-1	B2	Various	TEF	2.6E-8		
Dibenzo(a,h)anthracene	9.90E-9	7.3E+0	B2	Various	TEF	7.2E-8		
Arsenic	7.18E-8	1.5E+0	A	Various	IRIS	1.1E-7		
Lead	2.88E-7	Inappropriate For Evaluation				--		
							6E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	1.34E-10	7.5E-3	B2	Liver	IRIS	1.0E-12		
Benzo(a)anthracene	7.60E-9	7.3E-1	B2	Various	TEF*	5.6E-9		
Chrysene	6.93E-9	7.3E-3	B2	Various	TEF	5.1E-11		
Bis(2-ethylhexyl)phthalate	8.81E-9	1.4E-2	B2	Liver	IRIS	1.2E-10		
Benzo(k)flouranthene	8.07E-9	7.3E-2	B2	Various	TEF	5.9E-10		
Benzo(b)flouranthene	7.81E-9	7.3E-1	B2	Various	TEF	5.7E-9		
Benzo(a)pyrene	7.84E-9	7.3E+0	B2	Forestomach	IRIS	5.5E-8		
Ideno(1,2,3-cd)pyrene	6.97E-9	7.3E-1	B2	Various	TEF	5.1E-9		
Dibenzo(a,h)anthracene	1.98E-9	7.3E+0	B2	Various	TEF	1.5E-8		
Arsenic	1.43E-7	1.5E+0	A	Various	IRIS	2.15E-7		
Lead	5.74E-7	Inappropriate For Evaluation				--		
							3E-7	

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Table 2-11 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]								
Benzo(a)anthracene	8.81E-13	6.1E-1	B2	Various	TEF*	5.4E-13		
Chrysene	8.03E-13	6.1E-3	B2	Various	TEF	4.9E-15		
Benzo(k)flouranthene	9.35E-13	6.1E-2	B2	Various	TEF	5.7E-14		
Benzo(b)flouranthene	9.04E-13	6.1E-1	B2.	Various	TEF	5.5E-13		
Benzo(a)pyrene	9.08E-13	6.1E+0	B2	Various	EPA Reg. VI	5.5E-12		
Ideno(1,2,3-cd)pyrene	8.07E-13	6.1E-1	B2	Various	TEF	4.9E-13		
Dibenzo(a,h)anthracene	2.29E-13	6.1E+0	B2	Various	TEF	1.4E-12		
Arsenic	1.66E-11	5E+1	A	Lung	HEAST	8.3E-10		
Cadmium	2.02E-12	6.3E+0	B1	Lung	IRIS	1.3E-11		
Chromium	5.77E-11	4.1E+1[3]	A	Lung	HEAST	2.4E-9		
Lead	6.65E-11	Inappropriate For Evaluation				--		
							3E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	6.94E-9	1.65E-3	B2	Neoplasms	IRIS	1.2E-11		
							1E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1]								
Arsenic	4.60E-8	1.5E+0	A	Various	IRIS	6.9E-8		
Lead	4.14E-10	Inappropriate For Evaluation				--	7E-8	
								1E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.
[3] Chromium VI.
* TEF = toxicity equivalency factor relative to benzo(a)pyrene (USEPA 1993b).

Table 2-12. Cancer Risk Estimates, Site 1, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	1.34E-10	7.5E-3	B2	Liver	IRIS	1.0E-12		
Benzo(a)anthracene	7.60E-9	7.3E-1	B2	Various	TEF*	5.6E-9		
Chrysene	6.93E-9	7.3E-3	B2	Various	TEF	5.1E-11		
Bis(2-ethylhexyl)phthalate	8.80E-9	1.4E-2	B2.	Liver	IRIS	1.2E-10		
Benzo(k)flouranthene	8.08E-9	7.3E-2	B2	Various	TEF	5.9E-10		
Benzo(b)flouranthene	7.80E-9	7.3E-1	B2	Various	TEF	5.7E-9		
Benzo(a)pyrene	7.85E-9	7.3E+0	B2	Forestomach	IRIS	5.7E-8		
Ideno(1,2,3-cd)pyrene	6.98E-9	7.3E-1	B2	Various	TEF	5.1E-9		
Dibenzo(a,h)anthracene	1.98E-9	7.3E+0	B2	Various	TEF	1.5E-8		
Arsenic	1.44E-8	1.5E+0	A	Various	IRIS	2.2E-8		
Lead	5.75E-8	Inappropriate For Evaluation				--		
							1E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	1.34E-10	7.5E-3	B2	Liver	IRIS	1.0E-12		
Benzo(a)anthracene	7.60E-9	7.3E-1	B2	Various	TEF*	5.6E-9		
Chrysene	6.93E-9	7.3E-3	B2	Various	TEF	5.1E-11		
Bis(2-ethylhexyl)phthalate	8.81E-9	1.4E-2	B2	Liver	IRIS	1.2E-10		
Benzo(k)flouranthene	8.07E-9	7.3E-2	B2	Various	TEF	5.9E-10		
Benzo(b)flouranthene	7.81E-9	7.3E-1	B2	Various	TEF	5.7E-9		
Benzo(a)pyrene	7.84E-9	7.3E+0	B2	Forestomach	IRIS	5.7E-8		
Ideno(1,2,3-cd)pyrene	6.97E-9	7.3E-1	B2	Various	TEF	5.1E-9		
Dibenzo(a,h)anthracene	1.98E-9	7.3E+0	B2	Various	TEF	1.5E-8		
Arsenic	1.43E-7	1.5E+0	A	Various	IRIS	2.2E-7		
Lead	5.74E-7	Inappropriate For Evaluation				--		
							3E-7	

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Table 2-12 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]								
Benzo(a)anthracene	8.81E-13	6.1E-1	B2	Various	TEF*	5.4E-13		
Chrysene	8.03E-13	6.1E-3	B2	Various	TEF	4.9E-15		
Benzo(k)flouranthene	9.35E-13	6.1E-2	B2	Various	TEF	5.7E-14		
Benzo(b)flouranthene	9.04E-13	6.1E-1	B2.	Various	TEF	5.5E-13		
Benzo(a)pyrene	9.08E-13	6.1E+0	B2	Various	EPA Reg. VI	5.5E-12		
Ideno(1,2,3-cd)pyrene	8.07E-13	6.1E-1	B2	Various	TEF	4.9E-13		
Dibenzo(a,h)anthracene	2.29E-13	6.1E+0	B2	Various	TEF	1.4E-12		
Arsenic	1.66E-11	5E+1	A	Lung	HEAST	8.3E-10		
Cadmium	2.02E-12	6.3E+0	B1	Lung	IRIS	1.3E-11		
Chromium	5.77E-11	4.1E+1	A	Lung	HEAST	2.4E-9		
Lead	6.65E-11	Inappropriate For Evaluation				--		
							3E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	6.94E-9	1.65E-3	B2	Neoplasms	IRIS	1.2E-11		
							1E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1]								
Arsenic	4.60E-8	1.5E+0	A	Various	IRIS	6.9E-8		
Lead	4.14E-10	Inappropriate For Evaluation				--	7E-8	
								5E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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2.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of Site 1 would be identical to those developed for current land use and presented above. Risk estimates developed for future industrial land use at LHAAP Site 1 are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

2.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use at Site 1 are presented in Tables 2-13 and 2-14 for RME and CTE, respectively. For these estimates, a major contributor to total risk is exposure to chromium via groundwater ingestion (pathway-specific hazard quotients of 1E-1 and 8E-2 for RME and CTE, respectively). Estimated risks associated with chromium ingestion in groundwater may be overestimated due to the use of maximum detected values and the use of an RfD for Chromium VI (most conservative species). It should also be emphasized that all chromium concentrations in groundwater at Site 1 were well within the LHAAP background range (Table 2-1). Total site exposure HIs of 4E-1 and 2E-1 are also well-below the critical value of 1.0 and do not indicate concern for non-cancer health effects associated with future industrial use of LHAAP Site 1. Additionally, lead concentrations are well-below the 2,000 ppm screening level for adult non-residential exposure (see Section 2.4.2). As with estimates for recreational exposure, a lack of toxicity data for non-cancer health effects associated with exposure to PAHs detected at the site should be considered in evaluation of these estimates.

2.5.3.2 Cancer Risk Estimates. Cancer risk estimates for future industrial land use are presented in Tables 2-15 and 2-16 for RME and CTE, respectively. Similar to estimates for recreational land use, cancer risk for this scenario is driven by exposure to PAHs at the site via dermal contact. Total exposure risk estimates of 7E-6 (RME) and 1E-6 (CTE) are well within the acceptable cancer risk range and do not indicate a concern for cancer-related health effects associated with future industrial use of LHAAP Site 1. With the exception of lead, toxicity values were available for all evaluated carcinogens, resulting in increased confidence in these estimates.

Table 2-13. Hazard Index Estimates, Site 1, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Acetone	4.95E-7	1E-1	Organ weights	IRIS	1,000	1	5.0E-6		
Methylene Chloride	2.00E-7	6E-2	Liver toxicity	IRIS	100	1	3.3E-7		
Toluene	1.50E-8	2E-1	Organ weights	IRIS	1,000	1	7.5E-8		
Xylene	1.50E-8	2E+0	Hyperactivity	IRIS	100	1	7.5E-9		
2-Butanone	1.15E-7	6E-1	Decr. birth weight	IRIS	3,000	1	1.9E-7		
Benzoic Acid	5.55E-6	4E+0	None given	IRIS	1	1	1.4E-6		
Phenanthrene	1.15E-6	Under Review							
Fluoranthene	1.29E-6	4E-2	Nephropathy	IRIS	3,000	1	3.3E-5		
Pyrene	1.22E-6	3E-2	Kidney effects	IRIS	3,000	1	4.0E-5		
Benzo(a)anthracene	1.02E-6								
Chrysene	1.00E-6								
Bis(2-ethylhexyl)phthalate	1.17E-6	2E-2	Incr. liver weight	IRIS	1,000	1	5.8E-5		
Benzo(k)flouranthene	1.03E-6								
Benzo(b)flouranthene	1.03E-6								
Benzo(a)pyrene	1.02E-6								
Ideno(1,2,3-cd)pyrene	9.35E-7								
Dibenzo(a,h)anthracene	2.95E-7								
Benzo(g,h,i)perylene	9.30E-7								
Antimony	3.30E-7	2E-5	Longevity	IRIS	1,000	1	2.0E-2		
Arsenic	1.98E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.0E-2		
Barium	3.30E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Cadmium	2.60E-7	3E-4	Proteinuria	IRIS	10	1	8.7E-4		
Chromium	7.65E-6	2.5E-4[3]	None given	IRIS	500	1	3.0E-2		
Lead	6.48E-6	Inappropriate For Evaluation							
Mercury	3.50E-8	1.5E-5	Hand tremor	EPA Reg. VI			2.3E-3		
Nickel	3.60E-6	1.0E-3	Decreased weight	IRIS	300	1	3.6E-3		
Selenium	2.10E-7	2.5E-4	Selenosis	IRIS	3	1	8.4E-4		
Silver	4.75E-7	2.5E-4	Argyria	IRIS	3	1	1.9E-3		
								8E-2	

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Table 2-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Acetone	4.84E-8	1E-1	Organ weights	IRIS	1,000	1	4.8E-7		
Methylene Chloride	1.96E-9	6E-2	Liver toxicity	IRIS	100	1	3.3E-8		
Toluene	1.47E-9	2E-1	Organ weights	IRIS	1,000	1	7.4E-9		
Xylene	1.47E-9	2E+0	Hyperactivity	IRIS	100	1	7.4E-10		
2-Butanone	1.12E-8	6E-1	Decr. birth weight	IRIS	3,000	1	1.9E-8		
Benzoic Acid	5.44E-7	4E+0	None given	IRIS	1	1	1.4E-7		
Phenanthrene	1.12E-7	Under Review							
Fluoranthene	1.26E-7	4E-2	Nephropathy	IRIS	3,000	1	3.2E-6		
Pyrene	1.19E-7	3E-2	Kidney effects	IRIS	3,000	1	4.0E-6		
Benzo(a)anthracene	9.93E-8								
Chrysene	9.78E-8								
Bis(2-ethylhexyl)phthalate	1.14E-7	2E-2	Incr. liver weight	IRIS	1,000	1	5.7E-6		
Benzo(k)flouranthene	1.01E-7								
Benzo(b)flouranthene	1.01E-7								
Benzo(a)pyrene	9.98E-8								
Ideno(1,2,3-cd)pyrene	9.14E-8								
Dibenzo(a,h)anthracene	2.89E-8								
Benzo(g,h,i)perylene	9.10E-8								
Antimony	3.23E-7	4E-4	Longevity	IRIS	1,000	1	8.1E-4		
Arsenic	1.99E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	6.6E-3		
Barium	3.22E-5	7E-2	Incr. blood press.	IRIS	3	1	4.6E-4		
Cadmium	2.54E-7	1E-3	Proteinuria	IRIS	10	1	2.5E-4		
Chromium	7.45E-6	5E-3	None given	IRIS	500	1	1.5E-3		
Lead	6.33E-6	Inappropriate For Evaluation							
Mercury	3.42E-8	3E-4	Hand tremor	EPA Reg. VI			1.1E-4		
Nickel	3.52E-6	2E-2	Decreased weight	IRIS	300	1	1.8E-4		
Selenium	2.05E-7	5E-3	Selenosis	IRIS	3	1	4.1E-5		
Silver	4.65E-7	5E-3	Argyria	IRIS	3	1	9.3E-5		
								1E-2	

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Table 2-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Benzoic Acid	1.26E-10								
Phenanthrene	2.60E-11								
Fluoranthene	2.92E-11								
Pyrene	2.75E-11								
Benzo(a)anthracene	2.29E-11								
Chrysene	2.26E-11								
Bis(2-ethylhexyl)phthalate	2.63E-11								
Benzo(k)flouranthene	2.33E-11								
Benzo(b)flouranthene	2.33E-11								
Benzo(a)pyrene	2.31E-11								
Ideno(1,2,3-cd)pyrene	2.11E-11								
Dibenzo(a,h)anthracene	6.67E-12								
Benzo(g,h,i)perylene	2.10E-11								
Antimony	7.46E-11								
Arsenic	4.46E-10								
Barium	7.43E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.8E-4		
Cadmium	5.88E-11								
Chromium	1.72E-9								
Lead	1.46E-9								
Mercury	7.91E-12	8.58E-5	Hand tremor	EPA Reg. VI			9.2E-8		
Nickel	8.12E-10								
Selenium	4.75E-11								
Silver	1.07E-10							2E-4	

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Table 2-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Acetone	1.83E-6								
Methylene Chloride	2.02E-7	2.45E-1	Liver toxicity	EPA Reg. VI			8.2E-7		
Toluene	7.72E-8	1.14E-1	Organ weight	IRIS	300	1	6.8E-7		
Xylene	9.34E-8	5.72E-2	Hyperactivity	EPA Reg. VI			1.6E-6		
2-Butanone	5.04E-7	2.86E-1	Decr. birth wt.	IRIS	1,000	1	1.8E-6		
								5E-6	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Toluene	3.00E-5	2E-1	Organ weights	IRIS	1,000	1	1.5E-4		
Arsenic	1.34E-6	3E-4	Hyperpigmentation	IRIS	3	1	4.5E-3		
			Vascular problems	IRIS					
Barium	3.00E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Chromium	4.02E-6	2.5E-4	None given	IRIS	500	1	2.0E-2		
Lead	1.21E-8	Inappropriate For Evaluation							
Nickel	1.34E-6	1.0E-3	Decreased weight	IRIS	300	1	1.3E-3		
								4E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
2-Butanone	2.49E-6	6E-1	Decr. birth wt.	IRIS	3,000	1	4.2E-6		
Acetone	4.02E-7	1E-1	Organ weights	IRIS	1,000	1	4.0E-6		
Isophorone	7.94E-7	2E-1	None given	IRIS	1,000	1	4.0E-6		
Barium	1.21E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.5E-3		
Chromium	2.19E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Nickel	2.42E-6	1.0E-3	Decreased weight	IRIS	300	1	2.4E-3		
								2E-2	

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Table 2-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
2-Butanone	1.86E-4	6E-1	Decr. birth wt.	IRIS	1,000	1	3.1E-4		
Acetone	1.76E-4	1E-1	Liver toxicity	EPA Reg. VI			1.8E-3		
Isophorone	9.78E-6	2E-1	Organ weight	IRIS	300	1	4.9E-5		
Barium	3.03E-3	7E-2	Hyperactivity	EPA Reg. VI			4.3E-2		
Chromium	5.48E-4	5E-3	Decr. birth wt.	IRIS	1,000	1	1.1E-1		
Nickel	6.06E-4	2E-2	Decr. birth wt.	IRIS	1,000	1	3.0E-2		
								2E-1	
									4E-1

[1] Intakes are dermally absorbed doses.

[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.

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Table 2-14. Hazard Index Estimates, Site 1, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Acetone	9.68E-8	1E-1	Organ weights	IRIS	1,000	1	9.8E-7		
Methylene Chloride	3.90E-9	6E-2	Liver toxicity	IRIS	100	1	6.5E-8		
Toluene	2.93E-9	2E-1	Organ weights	IRIS	1,000	1	1.5E-8		
Xylene	2.93E-9	2E+0	Hyperactivity	IRIS	100	1	1.5E-9		
2-Butanone	2.25E-8	6E-1	Decr. birth weight	IRIS	3,000	1	3.8E-8		
Benzoic Acid	1.09E-6	4E+0	None given	IRIS	1	1	2.7E-7		
Phenanthrene	2.25E-7	Under Review							
Fluoranthene	2.53E-7	4E-2	Nephropathy	IRIS	3,000	1	6.3E-6		
Pyrene	2.38E-7	3E-2	Kidney effects	IRIS	3,000	1	8.0E-6		
Benzo(a)anthracene	1.99E-7								
Chrysene	1.96E-7								
Bis(2-ethylhexyl)phthalate	2.28E-7	2E-2	Incr. liver weight	IRIS	1,000	1	1.2E-5		
Benzo(k)flouranthene	2.01E-7								
Benzo(b)flouranthene	2.01E-7								
Benzo(a)pyrene	2.00E-7								
Ideno(1,2,3-cd)pyrene	1.83E-7								
Dibenzo(a,h)anthracene	5.78E-8								
Benzo(g,h,i)perylene	1.82E-7								
Antimony	6.45E-8	2E-5	Longevity	IRIS	1,000	1	3.2E-3		
Arsenic	3.85E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.3E-3		
Barium	6.43E-6	3.5E-3	Incr. blood press.	IRIS	3	1	1.8E-3		
Cadmium	5.08E-8	3E-4	Proteinuria	IRIS	10	1	1.7E-4		
Chromium	1.49E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Lead	1.27E-6	Inappropriate For Evaluation							
Mercury	6.85E-9	1.5E-5	Hand tremor	EPA Reg. VI			4.6E-4		
Nickel	7.03E-7	1.0E-3	Decreased weight	IRIS	300	1	7.0E-4		
Selenium	4.10E-8	2.5E-4	Selenosis	IRIS	3	1	1.6E-4		
Silver	9.28E-8	2.5E-4	Argyria	IRIS	3	1	3.7E-4		
								2E-2	

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Table 2-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Acetone	4.84E-8	1E-1	Organ weights	IRIS	1,000	1	4.8E-7		
Methylene Chloride	1.96E-9	6E-2	Liver toxicity	IRIS	100	1	3.3E-8		
Toluene	1.47E-9	2E-1	Organ weights	IRIS	1,000	1	7.4E-9		
Xylene	1.47E-9	2E+0	Hyperactivity	IRIS	100	1	7.4E-10		
2-Butanone	1.12E-8	6E-1	Decr. birth weight	IRIS	3,000	1	1.9E-8		
Benzoic Acid	5.44E-7	4E+0	None given	IRIS	1	1	1.4E-7		
Phenanthrene	1.12E-7	Under Review							
Fluoranthene	1.26E-7	4E-2	Nephropathy	IRIS	3,000	1	3.2E-6		
Pyrene	1.19E-7	3E-2	Kidney effects	IRIS	3,000	1	4.0E-6		
Benzo(a)anthracene	9.93E-8								
Chrysene	9.78E-8								
Bis(2-ethylhexyl)phthalate	1.14E-7	2E-2	Incr. liver weight	IRIS	1,000	1	5.7E-6		
Benzo(k)flouranthene	1.01E-7								
Benzo(b)flouranthene	1.01E-7								
Benzo(a)pyrene	9.98E-8								
Ideno(1,2,3-cd)pyrene	9.14E-8								
Dibenzo(a,h)anthracene	2.89E-8								
Benzo(g,h,i)perylene	9.10E-8								
Antimony	3.23E-7	4E-4	Longevity	IRIS	1,000	1	8.1E-4		
Arsenic	1.93E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	6.6E-3		
Barium	3.22E-5	7E-2	Incr. blood press.	IRIS	3	1	4.6E-4		
Cadmium	2.54E-7	1E-3	Proteinuria	IRIS	10	1	2.5E-4		
Chromium	7.45E-6	5E-3	None given	IRIS	500	1	1.5E-3		
Lead	6.33E-6	Inappropriate For Evaluation							
Mercury	3.42E-8	3E-4	Hand tremor	EPA Reg. VI			1.1E-4		
Nickel	3.52E-6	2E-2	Decreased weight	IRIS	300	1	1.8E-4		
Selenium	2.05E-7	5E-3	Selenosis	IRIS	3	1	4.1E-5		
Silver	4.65E-7	5E-3	Argyria	IRIS	3	1	9.3E-5		
								1E-2	

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Table 2-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Benzoic Acid	1.26E-10								
Phenanthrene	2.60E-11								
Fluoranthene	2.92E-11								
Pyrene	2.75E-11								
Benzo(a)anthracene	2.29E-11								
Chrysene	2.26E-11								
Bis(2-ethylhexyl)phthalate	2.63E-11								
Benzo(k)flouranthene	2.33E-11								
Benzo(b)flouranthene	2.33E-11								
Benzo(a)pyrene	2.31E-11								
Ideno(1,2,3-cd)pyrene	2.11E-11								
Dibenzo(a,h)anthracene	6.67E-12								
Benzo(g,h,i)perylene	2.10E-11								
Antimony	7.46E-11								
Arsenic	4.46E-10								
Barium	7.43E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.8E-4		
Cadmium	5.88E-11								
Chromium	1.72E-9								
Lead	1.46E-9								
Mercury	7.91E-12	8.58E-5	Hand tremor	EPA Reg. VI			9.2E-8		
Nickel	8.12E-10								
Selenium	4.75E-11								
Silver	1.07E-10								
								2E-4	

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Table 2-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Acetone	1.83E-6								
Methylene Chloride	2.02E-7	2.45E-1	Liver toxicity	EPA Reg. VI			8.2E-7		
Toluene	7.72E-8	1.14E-1	Organ weight	IRIS	300	1	6.8E-7		
Xylene	9.34E-8	5.72E-2	Hyperactivity	EPA Reg. VI			1.6E-6		
2-Butanone	5.04E-7	2.86E-1	Decr. birth wt.	IRIS	1,000	1	1.8E-6		
								5E-6	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Toluene	3.00E-5	2E-1	Organ weights	IRIS	1,000	1	1.5E-4		
Arsenic	1.34E-6	3E-4	Hyperpigmentation	IRIS	3	1	4.5E-3		
			Vascular problems	IRIS					
Barium	3.00E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Chromium	4.02E-6	2.5E-4	None given	IRIS	500	1	2.0E-2		
Lead	1.21E-8	Inappropriate For Evaluation							
Nickel	1.34E-6	1.0E-3	Decreased weight	IRIS	300	1	1.3E-3		
								4E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
2-Butanone	2.49E-6	6E-1	Decr. birth wt.	IRIS	3,000	1	4.2E-6		
Acetone	4.02E-7	1E-1	Organ weights	IRIS	1,000	1	4.0E-6		
Isophorone	7.94E-7	2E-1	None given	IRIS	1,000	1	4.0E-6		
Barium	1.21E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.5E-3		
Chromium	2.19E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Nickel	2.42E-6	1.0E-3	Decreased weight	IRIS	300	1	2.4E-3		
								2E-2	

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Table 2-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
2-Butanone	1.30E-4	6E-1	Decr. birth wt.	IRIS	1,000	1	2.2E-4		
Acetone	1.23E-4	1E-1	Liver toxicity	EPA Reg. VI			1.2E-3		
Isophorone	6.85E-6	2E-1	Organ weight	IRIS	300	1	3.4E-5		
Barium	2.12E-3	7E-2	Hyperactivity	EPA Reg. VI			3.0E-2		
Chromium	3.84E-4	5E-3	Decr. birth wt.	IRIS	1,000	1	7.7E-2		
Nickel	4.25E-4	2E-2	Decr. birth wt.	IRIS	1,000	1	2.1E-2		
								1E-1	
									2E-1

[1] Intakes are dermally absorbed doses.

[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.

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Table 2-15. Cancer Risk Estimates, Site 1, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	7.00E-9	7.5E-3	B2	Liver	IRIS	5.3E-11		
Benzo(a)anthracene	3.55E-7	7.3E-1	B2	Various	TEF*	2.6E-7		
Chrysene	3.50E-7	7.3E-3	B2	Various	TEF	2.6E-9		
Bis(2-ethylhexyl)phthalate	4.08E-7	1.4E-2	B2.	Liver	IRIS	5.7E-9		
Benzo(k)flouranthene	3.60E-7	7.3E-2	B2	Various	TEF	2.6E-8		
Benzo(b)flouranthene	3.60E-7	7.3E-1	B2	Various	TEF	2.6E-7		
Benzo(a)pyrene	3.58E-7	7.3E+0	B2	Forestomach	IRIS	2.6E-6		
Ideno(1,2,3-cd)pyrene	3.28E-7	7.3E-1	B2	Various	TEF	2.4E-7		
Dibenzo(a,h)anthracene	1.03E-7	7.3E+0	B2	Various	TEF	7.5E-7		
Arsenic	6.93E-7	1.5E+0	A	Various	IRIS	1.0E-6		
Lead	2.27E-6	Inappropriate For Evaluation				--		
							5E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	6.96E-10	7.5E-3	B2	Liver	IRIS	5.2E-12		
Benzo(a)anthracene	3.53E-8	7.3E-1	B2	Various	TEF	2.6E-8		
Chrysene	3.48E-8	7.3E-3	B2	Various	TEF	2.5E-10		
Bis(2-ethylhexyl)phthalate	4.05E-8	1.4E-2	B2	Liver	IRIS	5.7E-10		
Benzo(k)flouranthene	3.58E-8	7.3E-2	B2	Various	TEF	2.6E-9		
Benzo(b)flouranthene	3.58E-8	7.3E-1	B2	Various	TEF	2.6E-8		
Benzo(a)pyrene	3.55E-8	7.3E+0	B2	Forestomach	IRIS	2.6E-7		
Ideno(1,2,3-cd)pyrene	3.25E-8	7.3E-1	B2	Various	TEF	2.4E-8		
Dibenzo(a,h)anthracene	1.03E-8	7.3E+0	B2	Various	TEF	7.5E-8		
Arsenic	6.87E-7	1.5E+0	A	Various	IRIS	1.0E-6		
Lead	2.25E-6	Inappropriate For Evaluation				--		
							1E-6	

019870

Table 2-15 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]								
Benzo(a)anthracene	8.20E-12	6.1E-1	B2	Various	TEF*	5.0E-12		
Chrysene	8.08E-12	6.1E-3	B2	Various	TEF	4.9E-14		
Benzo(k)flouranthene	8.32E-12	6.1E-2	B2	Various	TEF	5.1E-13		
Benzo(b)flouranthene	8.32E-12	6.1E-1	B2.	Various	TEF	5.1E-12		
Benzo(a)pyrene	8.24E-12	6.1E+0	B2	Various	EPA Reg. VI	5.0E-11		
Ideno(1,2,3-cd)pyrene	7.55E-12	6.1E-1	B2	Various	TEF	4.6E-12		
Dibenzo(a,h)anthracene	2.38E-12	6.1E+0	B2	Various	TEF	1.5E-11		
Arsenic	1.60E-10	5E+1	A	Lung	HEAST	8.0E-9		
Cadmium	2.10E-11	6.3E+0	B1	Lung	IRIS	1.3E-10		
Chromium	6.15E-10	4.1E+1	A	Lung	HEAST	2.5E-8		
Lead	5.23E-10	Inappropriate For Evaluation				--		
							3E-8	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	7.23E-8	1.65E-3	B2	Neoplasms	IRIS	1.2E-10		
							1E-10	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1]								
Arsenic	4.78E-7	1.5E+0	A	Various	IRIS	7.2E-7		
Lead	4.31E-9	Inappropriate For Evaluation				--	7E-7	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Isophorone	2.83E-7	9.5E-4	C	Preputial gland	IRIS	2.7E-10		
							3E-10	

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Table 2-15 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Ingestion of Groundwater								
Isophorone	3.49E-6	9.5E-4	C	Preputial gland	IRIS	3.3E-9		
							3E-9	
								7E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

Table 2-16. Cancer Risk Estimates, Site 1, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	5.03E-10	7.5E-3	B2	Liver	IRIS	3.8E-12		
Benzo(a)anthracene	2.55E-8	7.3E-1	B2	Various	TEF*	1.9E-8		
Chrysene	2.53E-8	7.3E-3	B2	Various	TEF	1.9E-10		
Bis(2-ethylhexyl)phthalate	2.93E-8	1.4E-2	B2.	Liver	IRIS	4.1E-10		
Benzo(k)flouranthene	2.60E-8	7.3E-2	B2	Various	TEF	1.9E-9		
Benzo(b)flouranthene	2.60E-8	7.3E-1	B2	Various	TEF	1.9E-8		
Benzo(a)pyrene	2.58E-8	7.3E+0	B2	Forestomach	IRIS	1.9E-7		
Ideno(1,2,3-cd)pyrene	2.35E-8	7.3E-1	B2	Various	TEF	1.7E-8		
Dibenzo(a,h)anthracene	7.43E-9	7.3E+0	B2	Various	TEF	5.4E-8		
Arsenic	4.98E-8	1.5E+0	A	Various	IRIS	7.5E-8		
Lead	1.63E-7	Inappropriate For Evaluation				--		
							4E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	2.53E-10	7.5E-3	B2	Liver	IRIS	1.9E-12		
Benzo(a)anthracene	1.28E-8	7.3E-1	B2	Various	TEF	9.3E-9		
Chrysene	1.26E-8	7.3E-3	B2	Various	TEF	9.2E-11		
Bis(2-ethylhexyl)phthalate	1.47E-8	1.4E-2	B2	Liver	IRIS	2.1E-10		
Benzo(k)flouranthene	1.30E-8	7.3E-2	B2	Various	TEF	9.5E-10		
Benzo(b)flouranthene	1.30E-8	7.3E-1	B2	Various	TEF	9.5E-9		
Benzo(a)pyrene	1.28E-8	7.3E+0	B2	Forestomach	IRIS	9.3E-8		
Ideno(1,2,3-cd)pyrene	1.18E-8	7.3E-1	B2	Various	TEF	8.6E-9		
Dibenzo(a,h)anthracene	3.71E-9	7.3E+0	B2	Various	TEF	3.6E-8		
Arsenic	2.48E-7	1.5E+0	A	Various	IRIS	3.7E-7		
Lead	8.15E-7	Inappropriate For Evaluation				--		
							5E-7	

019873

Table 2-16 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]								
Benzo(a)anthracene	2.94E-12	6.1E-1	B2	Various	TEF*	1.8E-12		
Chrysene	2.90E-12	6.1E-3	B2	Various	TEF	1.7E-14		
Benzo(k)flouranthene	2.99E-12	6.1E-2	B2	Various	TEF	1.8E-13		
Benzo(b)flouranthene	2.99E-12	6.1E-1	B2.	Various	TEF	1.8E-12		
Benzo(a)pyrene	2.96E-12	6.1E+0	B2	Various	EPA Reg. VI	1.8E-11		
Ideno(1,2,3-cd)pyrene	2.71E-12	6.1E-1	B2	Various	TEF	1.7E-12		
Dibenzo(a,h)anthracene	8.56E-13	6.1E+0	B2	Various	TEF	5.22E-12		
Arsenic	5.73E-11	5E+1	A	Lung	HEAST	2.9E-9		
Cadmium	7.54E-12	6.3E+0	B1	Lung	IRIS	4.8E-11		
Chromium	2.21E-10	4.1E+1	A	Lung	HEAST	9.1E-9		
Lead	1.88E-10	Inappropriate For Evaluation				--		
							1E-8	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	2.60E-8	1.65E-3	B2	Neoplasms	IRIS	4.3E-11		
							4E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1]								
Arsenic	1.72E-7	1.5E+0	A	Various	IRIS	2.6E-7		
Lead	1.55E-9	Inappropriate For Evaluation				--	3E-7	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Isophorone	1.02E-7	9.5E-4	C	Preputial gland	IRIS	9.7E-11		
							1E-10	

019874

Table 2-16 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Ingestion of Groundwater								
Isophorone	8.80E-7	9.5E-4	C	Preputial gland	IRIS	8.4E-10		
							8E-10	
								1E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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2.5.4 Uncertainties Associated with Risk Estimates. Estimates of potential risk to human health from contaminant release at LHAAP Site 1 have been presented in this baseline risk assessment. Associated with these estimates are uncertainties in the risk calculation process as well as underlying assumptions forming the basis for risk evaluation. While some of these uncertainties have been briefly discussed throughout this report, further discussion of several areas of uncertainty is provided below.

As estimated risks for some exposure scenarios at LHAAP Site 1 appear to be driven by exposure to PAHs detected at the site, uncertainties regarding risk calculation for this group of compounds should be identified and considered in risk management decisions. As previously identified, a complete lack of toxicological information regarding non-cancer effects of PAH exposure on human health is an uncertainty for HI estimates. This may result in underestimation of noncarcinogenic risks for these exposure scenarios. However, estimated risks associated with exposure to PAHs at Site 1 should also be evaluated with consideration given to frequency of detection issues at the site. Most PAH compounds were detected in only three (3) of a total of fifty-two (52) combined soil and ditch sediment samples at LHAAP Site 1 (Tables 2-2 and 2-4). For calculation of exposure estimates, this resulted in the use of one-half the detection limits for all other samples. Impacts of this protocol on exposure concentrations and resulting risk estimates for PAH exposure is an area of uncertainty and should be considered for this assessment.

As exposure via dermal contact contributed to site risk, uncertainties for this pathway were evaluated. An area of uncertainty for this pathway is the use of absorption-corrected oral toxicity data in risk characterization. While this is the approach currently recommended by the USEPA, it is recognized that use of these values may lead to considerable uncertainty and potential over- or underestimation of risk associated with dermal contact (USEPA 1992c). In addition, use of assumed skin surface areas available for contact for site receptors (Table 1-1) may overestimate or underestimate exposure under both land use scenarios and may contribute to uncertainty for estimates involving dermal contact.

Some degree of uncertainty also exists for non-cancer risk estimates for pathways involving inhalation. Reference concentrations (and resulting calculated inhalation RfDs) are lacking for many chemicals evaluated for this pathway. This area of uncertainty should be considered in interpretation of non-cancer risk estimates.

2.5.5 Risk Summarization. Total risk estimates derived as a result of this baseline risk assessment are summarized in Table 2-17. While these values are provided and discussed above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline risk assessment do not indicate any unacceptable risk to human health associated with continued current or future land uses at Site 1 in the absence of site remediation.

Table 2-17. Summary of Baseline Risk Estimates
Site 1, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	4E-2	Chromium/Dermal Contact (Soil)
CTE	2E-2	Chromium/Dermal Contact (Water)
Cancer Risk		
RME	1E-6	PAH Compounds/Dermal Contact (Soil)
CTE	5E-7	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	4E-1	Chromium*/Groundwater Ingestion
CTE	2E-1	Chromium*/Groundwater Ingestion
Cancer Risk		
RME	7E-6	PAH Compounds/Dermal Contact (Soil)
CTE	1E-6	Arsenic*/Soil Ingestion

* All concentrations within LHAAP facility background range.

2.6 SUMMARY

2.6.1 General. A baseline risk assessment was prepared to support site management decisions for LHAAP Site 1 (Inert Burning Grounds). The assessment represents an estimate of potential human health impacts resulting from contaminant release from the site in the absence of remediation. Methodology used in the assessment was that prescribed by the USEPA.

2.6.2 Chemicals of Potential Concern. Chemicals of potential concern in site soils and ditch sediments included several VOCs, a variety of PAHs, and metals. Chemicals of concern in groundwater included several volatile organics and metals. With the exception of a few chemicals eliminated from evaluation due to detection in blank samples or not detected in verification sampling, all detected chemicals were carried through risk quantification procedures.

2.6.3 Exposure Assessment. Completed pathways for potential human exposure to site contaminants were identified for receptors under both current recreational and future industrial land use scenarios. Evaluated pathways for current recreational land use included dermal contact with soils, dermal contact with surface waters, incidental ingestion of soil, inhalation of released volatile compounds, and inhalation of particulates released from site soils. For future industrial land use, the same pathways were evaluated with the addition of groundwater ingestion and dermal contact with groundwater used as a water supply source. All estimation techniques, assumptions, methodology, and degrees of uncertainty associated with risk quantification are provided in this report. As a rule, conservative assumptions were used throughout the risk assessment process where possible.

2.6.4 Risk Characterization. Risk characterization for this assessment was conducted by comparison of estimated intakes of chemicals with toxicity values for carcinogenic and noncarcinogenic health effects. Ranges of cancer and non-cancer risk estimates for both current and future land use scenarios at LHAAP Site 1 are summarized in Table 2-17 of this document.

Total risk estimates for both cancer and non-cancer health effects for all land use scenarios were within acceptable risk ranges.

2.6.5 Conclusion. The objective of this baseline risk assessment was to provide an estimate of risk to human health at LHAAP Site 1 in the absence of remediation. Based on the assumptions, approaches, methods, and uncertainties presented in this document, unacceptable risk to human receptors was not identified. As such, this assessment fails to support the need for site remediation for protection of human health.

HUMAN HEALTH EVALUATION ADDENDUM

2A.1 INTRODUCTION AND OBJECTIVES

2A.1.1 Introduction. Following a review of Phase 1 and 2 data collected at LHAAP Site 1 and human health risk characterization based on these results (as previously presented in this chapter), limited additional surface soil sampling was conducted at the site. This sampling was initiated to support additional human health risk characterization for limited areas at Site 1 identified during review of original risk assessment results. Site-specific objectives for these additional evaluations, sampling results, and resulting additional risk estimates are presented in this addendum. Addendum results are in no way meant to replace or supersede original human health risk evaluations, but are provided as supplemental information for comprehensive risk evaluation at the site.

2A.1.2 Addendum Objectives. Additional surface soil sampling at Site 1 was conducted along a natural drainage area located near the center of the site where low concentrations of a variety of PAH compounds were detected in initial sampling. This triangular-shaped area covers approximately 0.25 acres and is generally bordered by monitoring well 01MW03, soil boring

01SB26, and former sediment sampling location 01SD09 (Figure 2-1). As this low-lying area represents a potential location for accumulation of surface contaminants, the primary objective of this addendum was to evaluate this limited area as a potential "hot spot" for human exposure as recommended in RAGS/HHEM (USEPA 1989). Additional objectives included verification of the similarity between chemical concentrations in 0- to 6-inch and slightly deeper soil depths employed in original risk evaluations and expansion of the number of metals used in risk evaluation.

2A.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2A.2.1 Addendum Sampling Activities. Surface soil sampling activities for Site 1 addendum risk evaluation are described in Section 5 of the Group 1 RI Report. In summary, surface soil (0- to 6-inch depth) samples were collected as follows: four (4) samples along a north-to-south line from 01MW03 to 01SB26 at approximate 50-foot intervals; five (5) samples from this line to 01SD09 in a west-to-east direction along the drainage pathway at approximate 50-foot intervals (see Figure 2-1 for well and boring locations). For QA/QC purposes, one sample was collected in triplicate. All sampling locations are provided in Figure 5-1 of the Group 1 RI report.

All samples were analyzed for semivolatile organic compounds (EPA Method 8270). In addition, one (1) sample near 01SB26 and one (1) sample along the east-to-west drainage line were analyzed for explosives (Method 8330) and the 23 Target Analyte List (TAL) metals.

2A.2.2 Addendum Sampling Results. Chemicals detected in addendum surface soil samples are summarized in Table 2A-1. Detected organics included PAHs which were detected at low frequencies and at concentrations very similar to those in Phase 1 and 2 results (compare to Table 2-2). Contrary to previous results, benzo(a)pyrene was not detected (quantitation limit range of 350 to 436 ug/Kg) in addendum sampling surface soils. A number of metals were detected at concentrations which sometimes exceeded background levels but were generally lower than those from previous sampling events (compare to Table 2-2).

Table 2A-1. Chemicals Detected in Soils[1]
Site 1 Addendum, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[2]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[3]
Organics (ug/Kg)				
Benzo(b)fluoranthene	3/10	350-436	416-878	--
Benzo(k)fluoranthene	3/10	350-436	456-701	--
Benzo(g,h,i)perylene	3/10	350-436	367-412	--
Fluoranthene	3/10	350-436	449-1,740	--
Benzo(a)anthracene	2/10	350-436	391-533	--
Chrysene	2/10	350-436	517-814	--
Phenanthrene	2/10	350-436	642-861	--
Pyrene	2/10	350-436	687-1,140	--
Metals (mg/Kg)				
Arsenic	3/3	--	2.57-4.13	2.3-29.7
Barium	3/3	--	34.9-72.2	35.1-287
Cadmium	2/3	2.64	3.61-4.05	1.25
Chromium	3/3	--	13.1-35.7	3.2-22.8
Nickel	3/3	--	6.37-7.03	1.5-6.3
Lead	3/3	--	13.6-22.8	2.6-17.4
Aluminum	3/3	--	2,270-6,490	1,270-20,700
Calcium	3/3	--	205-769	124-1,090
Cobalt	2/3	2.88	3.32-8.76	1.5-19.1
Copper	3/3	--	5.31-10.7	0.88-6.7
Iron	3/3	--	6,870-11,900	2,450-31,000
Potassium	3/3	--	151-612	133-481
Magnesium	3/3	--	128-396	68.4-474
Manganese	3/3	--	38.5-198	10.9-2,330
Vanadium	3/3	--	13.8-17.7	NA[4]
Zinc	3/3	--	17.2-22.6	3.4-16.2

[1] 0 to 6-inch depth.
[2] Includes quality control duplicate samples.
[3] Range of detected concentrations in surface (0-0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant, (USACE 1995b).
[4] Not available.

Explosive compounds were not detected in any field or quality control (QC) surface soil sample from the site. While not reported in field or QC samples, a single detection of HMX at the detection limit (0.26 mg/Kg) was reported in a quality assurance (QA) triplicate sample (sample RASS01-1-QA) analyzed by a separate laboratory. As a result, this location was resampled with no resulting detection of explosives although a slightly higher detection limit (0.9 mg/Kg) was reported. Based on these results, it appears that explosives at concentrations above common analytical detection limits are not present in this area.

2A.2.3 <u>Selection of Chemicals of Potential Concern</u>. Chemicals which are essential human nutrients and present at low concentrations are generally eliminated as chemicals of potential concern (COPC) in human health risk evaluation. These constituents commonly include iron, magnesium, calcium, and potassium (Supplemental Region VI Risk Assessment Guidance, May 1995). Accordingly, these chemicals were eliminated as COPC for this evaluation. With these exceptions, chemicals selected for use as COPC in quantitative human health risk assessment for pathways involving exposure to surface soils for this addendum included all detected chemicals listed in Table 2A-1. No other chemicals were eliminated and all were carried through to risk characterization.

2A.3 EXPOSURE ASSESSMENT

2A.3.1 <u>Identification of Exposure Pathways</u>. Land use assumptions and exposure pathways identical to those employed in original risk estimates (Table 2-5) were retained for this addendum. Accordingly, risk evaluations for current recreational, future recreational, and future industrial land uses and all associated exposure pathways were evaluated. These pathways are described in Section 2.3 of the original human health evaluation for Site 1.

In accordance with the objective of providing "hot spot" risk estimates for the site, quantified risks for all pathways involving dermal contact and incidental ingestion of soils were generated using only surface soil data collected for this addendum (Table 2A-1). Conceivably, chemical intakes for receptors exclusively using this limited area would also be influenced by exposure to other environmental media (groundwater, surface waters, and fugitive dust generated across the entire site). Therefore, as a measure of total cumulative risk to human receptors, risk estimates for these pathways, as established in the original assessment, were included in risk characterization for this addendum.

2A.3.2 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

2A.3.3 Summary of Exposure Concentrations. Exposure concentrations for all pathways involving dermal contact with soils and soil ingestion were estimated using maximum detected values (Table 2A-1). While 95% upper confidence limits (UCLs) on average concentrations in soils assuming lognormal data distributions are generally used in estimating exposure concentrations (and was used in original evaluation), small soil sample sizes for this addendum precluded use of this method. Sample size for metals analyses (n=2 excluding field duplicates) did not permit calculation of standard deviations necessary for UCL computation. While sample numbers were higher for organics (n=9), the same approach was used for these constituents for the sake of consistency among COPC. It should be emphasized that this approach adds conservatism to risk estimates as UCLs for many COPC (particularly PAHs) would be less than maximum detected values. Typically, maximum values are used only when UCLs exceed these concentrations (USEPA 1992b).

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Concentrations of COPC in soils to a depth of 5 feet were used in original exposure calculations for future industrial land use receptors (see Section 2.3.3.2). As subsurface soils were not collected for use in this addendum, data from surface soils were used in estimating exposure under industrial as well as recreational land use for this addendum. Accordingly, exposure concentrations for all pathways involving dermal contact with soils and soil ingestion for this addendum are presented in Table 2A-2.

2A.3.4 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations and variable values employed in original risk evaluations and presented in Chapter 1. Identical values and equations were retained for use in estimating intakes for this addendum. Estimated intake rates for all COPC are presented in the "Risk Characterization" section of this addendum.

2A.3.5 Identification of Uncertainties. Most areas of uncertainty and estimated magnitude of effects in exposure assessment identified in original risk evaluations for Site 1 (Section 2.3.4, Table 2-8) would be applicable to this addendum. An additional area of uncertainty would include the use of maximum detected concentrations for pathways involving soil exposure and would most likely result in overestimation of exposure for some chemicals. Similarly, uncertainty results from the use of only surface soils data for pathways involving soil exposure under future industrial land use scenarios. This may over- or underestimate exposure depending upon the extent of future excavation activities at this limited site area and relative differences between COPC concentrations in surface and subsurface soils.

Table 2A-2. Summary of Soil Exposure Concentrations, Current and Future Land Use, Site 1 Addendum, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists/Industrial Workers **Incidental ingestion of soil** **Dermal contact with soil**		
	mg/Kg	
Benzo(b)fluoranthene	0.878	Concentrations are maximum detected concentrations in addendum surface soil samples. Upper confidence limits not used due to small sample sizes.
Benzo(k)fluoranthene	0.701	
Benzo(g,h,i)perylene	0.412	
Fluoranthene	1.740	
Benzo(a)anthracene	0.533	
Chrysene	0.814	
Phenanthrene	0.861	
Pyrene	1.140	
Arsenic	4.13	
Barium	72.2	
Cadmium	4.05	
Chromium	35.7	
Nickel	7.03	
Lead	22.8	
Aluminum	6,490	
Cobalt	8.76	
Copper	10.7	
Manganese	198	
Vanadium	17.7	
Zinc	22.6	

2A.4 TOXICITY ASSESSMENT

Toxicological information for COPC at LHAAP Site 1 has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this addendum. Section 2.4 should be consulted for toxicity information related to chemicals of concern.

2A.5 RISK CHARACTERIZATION

2A.5.1 General. Risk characterization for this addendum was performed in an identical manner to that for the original assessment. Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios are all presented below.

2A.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at the limited area of Site 1 are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

2A.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for current recreational land use are presented in Tables 2A-3 and 2A-4 for RME and CTE, respectively. Evaluation of these estimates reveal that non-cancer risks are dominated by exposure to metals (principally chromium) via dermal contact with soils (pathway HI = 4E-2 and 1E-2 for RME and CTE, respectively). Total exposure HIs of 6E-2 and 3E-2 (RME and CTE, respectively) are extremely low and similar to those estimated for initial overall site risk (Table 2-17), are well below unity, and are not indicative of non-cancer health concerns for current land use at this limited area of Site 1. A lack of toxicological data for non-cancer health effects associated with PAHs at the site lends a degree of uncertainty to these estimates, and should be considered in interpretation of these results.

Table 2A-3. Hazard Index Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Benzo(b)fluoranthene	1.03E-6								
Benzo(k)fluoranthene	8.20E-7								
Benzo(g,h,i)perylene	4.82E-7								
Fluoranthene	2.04E-6	4E-2	Nephropathy	IRIS	3,000	1	5.1E-5		
Benzo(a)anthracene	6.24E-7								
Chrysene	9.52E-7								
Phenanthrene	1.01E-6	Under Review							
Pyrene	1.33E-6	3E-2	Kidney Effects	IRIS	3,000	1	4.4E-5		
Arsenic	4.83E-7	3E-4	Hyperpigmentation	IRIS	3	1	1.6E-3		
Barium	8.45E-6	3.5E-3	Blood pressure	IRIS	3	1	2.4E-3		
Cadmium	4.74E-7	3E-4	Proteinuria	IRIS	10	1	1.6E-3		
Chromium	4.18E-6	2.5E-4[2]	None given	IRIS	500	1	2.0E-2		
Nickel	8.23E-7	1.0E-3	Decreased weight	IRIS	300	1	8.2E-4		
Lead	2.67E-6	Inappropriate For Evaluation							
Aluminum	7.59E-4								
Cobalt	1.02E-6								
Copper	1.25E-6								
Manganese	2.32E-5	1E-2	CNS Effects	IRIS	1	1	2.3E-3		
Vanadium	2.07E-6	3.5E-4		HEAST			1.0E-2		
Zinc	2.64E-6	1.5E-2	ESOD Decrease	IRIS	3	1	1.8E-4		
								4E-2	

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Table 2A-3 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Benzo(b)fluoranthene	2.05E-7								
Benzo(k)flouranthene	1.64E-7								
Benzo(g,h,i)perylene	9.64E-8								
Fluoranthene	4.07E-7	4E-2	Nephropathy	IRIS	3,000	1	1.0E-5		
Benzo(a)anthracene	1.25E-7								
Chrysene	1.90E-7								
Phenanthrene	2.01E-7	Under Review							
Pyrene	2.67E-7	3E-2	Kidney Effects	IRIS	3,000	1	8.9E-6		
Arsenic	9.66E-7	3E-4	Hyperpigmentation	IRIS	3	1	3.2E-3		
Barium	1.69E-5	7E-2	Blood pressure	IRIS	3	1	2.4E-4		
Cadmium	9.48E-7	1E-3	Proteinuria	IRIS	10	1	9.5E-4		
Chromium	8.35E-6	5E-3[2]	None given	IRIS	500	1	1.7E-3		
Nickel	1.65E-6	2E-2	Decreased weight	IRIS	300	1	8.3E-5		
Lead	5.34E-6	Inappropriate For Evaluation							
Aluminum	1.52E-3								
Cobalt	2.05E-6								
Copper	2.50E-6								
Manganese	4.63E-5	1.4E-1	CNS Effects	IRIS	1	1	3.3E-4		
Vanadium	4.14E-6	7E-3		HEAST			5.9E-4		
Zinc	5.29E-6	3.0E-1	ESOD Decrease	IRIS	3	1	1.8E-5		
								1E-2	

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Table 2A-3 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[3]								5E-5	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[3]								1E-6	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[3]								1E-2	
									6E-2

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Value for Chromium VI.
[3] See Table 2-9.

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Table 2A-4. Hazard Index Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Benzo(b)fluoranthene	2.06E-7								
Benzo(k)fluoranthene	1.65E-7								
Benzo(g,h,i)perylene	9.68E-8								
Fluoranthene	4.09E-7	4E-2	Nephropathy	IRIS	3,000	1	1.0E-5		
Benzo(a)anthracene	1.25E-7								
Chrysene	1.91E-7								
Phenanthrene	2.02E-7	Under Review							
Pyrene	2.68E-7	3E-2	Kidney Effects	IRIS	3,000	1	8.9E-6		
Arsenic	9.71E-8	3E-4	Hyperpigmentation	IRIS	3	1	3.2E-4		
Barium	1.70E-6	3.5E-3	Blood pressure	IRIS	3	1	4.9E-4		
Cadmium	9.52E-8	3E-4	Proteinuria	IRIS	10	1	3.2E-4		
Chromium	8.39E-7	2.5E-4[2]	None given	IRIS	500	1	3.4E-3		
Nickel	1.65E-7	1.0E-3	Decreased weight	IRIS	300	1	1.7E-4		
Lead	5.36E-7	Inappropriate For Evaluation							
Aluminum	1.53E-4								
Cobalt	2.06E-7								
Copper	2.51E-7								
Manganese	4.65E-6	1E-2	CNS Effects	IRIS	1	1	4.7E-4		
Vanadium	4.16E-7	3.5E-4		HEAST			1.2E-3		
Zinc	5.31E-7	1.5E-2	ESOD Decrease	IRIS	3	1	3.5E-5		
								1E-2	

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Table 2A-4 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Benzo(b)fluoranthene	2.05E-7								
Benzo(k)flouranthene	1.64E-7								
Benzo(g,h,i)perylene	9.64E-8								
Fluoranthene	4.07E-7	4E-2	Nephropathy	IRIS	3,000	1	1.0E-5		
Benzo(a)anthracene	1.25E-7								
Chrysene	1.90E-7								
Phenanthrene	2.01E-7	Under Review							
Pyrene	2.67E-7	3E-2	Kidney Effects	IRIS	3,000	1	8.9E-6		
Arsenic	9.66E-7	3E-4	Hyperpigmentation	IRIS	3	1	3.2E-3		
Barium	1.69E-5	7E-2	Blood pressure	IRIS	3	1	2.4E-4		
Cadmium	9.48E-7	1E-3	Proteinuria	IRIS	10	1	9.5E-4		
Chromium	8.35E-6	5E-3[2]	None given	IRIS	500	1	1.7E-3		
Nickel	1.65E-6	2E-2	Decreased weight	IRIS	300	1	8.3E-5		
Lead	5.34E-6	Inappropriate For Evaluation							
Aluminum	1.52E-3								
Cobalt	2.05E-6								
Copper	2.50E-6								
Manganese	4.63E-5	1.4E-1	CNS Effects	IRIS	1	1	3.3E-4		
Vanadium	4.14E-6	7E-3		HEAST			5.9E-4		
Zinc	5.29E-6	3.0E-1	ESOD Decrease	IRIS	3	1	1.8E-5		
								1E-2	

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Table 2A-4 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[3]								5E-5	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[3]								1E-6	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[3]								1E-2	
									3E-2

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Value for Chromium VI.
[3] See Table 2-10.

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2A.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 2A-5 and 2A-6 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to PAH compounds and arsenic via dermal contact with site soils (total pathway risk = 3E-7 and 6E-8 for RME and CTE, respectively), and to a lesser degree, soil ingestion. It should be noted that all arsenic concentrations detected in addendum sampling were within surface soil background concentrations established for the facility (Table 2A-1). Total exposure risk estimates of 6E-7 and 3E-7 (RME and CTE, respectively) are actually lower than original risk estimates for the site as a whole (Table 2-17) and are well below the acceptable carcinogenic risk range. These results indicate no concern for cancer-related health effects for current land use practices. With the exception of lead, toxicity values were available for all evaluated carcinogens, lending increased confidence to these estimates.

2A.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of the limited area at Site 1 (represented by addendum sampling) would be identical to those presented above. Risk estimates developed for future industrial land use for this area are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

2A.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use are presented in Tables 2A-7 and 2A-8 for RME and CTE, respectively. For these estimates, a major contributor to total risk is exposure to chromium via groundwater ingestion (pathway-specific hazard quotients of 1E-1 and 8E-2 for RME and CTE, respectively). Estimated risks associated with chromium ingestion in groundwater may be overestimated owing to the use of maximum detected values and the use of an oral RfD for Chromium VI (most conservative species). It should also be emphasized that all chromium concentrations in groundwater at Site 1 were well within the LHAAP background range (Table 2-1). Total site exposure HIs of 4E-1 and 2E-1 are identical to those for original risk estimates for the site as a whole, are well below the critical value of 1.0, and therefore do not indicate concern for non-cancer health effects associated with future industrial land use of this limited area of Site 1. As with estimates for recreational exposure, a lack of toxicological data for non-cancer health effects

Table 2A-5. Cancer Risk Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Benzo(a)anthracene	8.95E-8	7.3E-1	B2	Various	TEF*	6.5E-8		
Chrysene	1.37E-7	7.3E-3	B2	Various	TEF	1.0E-9		
Benzo(k)flouranthene	1.18E-7	7.3E-2	B2	Various	TEF	8.6E-9		
Benzo(b)flouranthene	1.48E-7	7.3E-1	B2	Various	TEF	1.1E-7		
Arsenic	6.94E-8	1.5E+0	A	Various	IRIS	1.0E-7		
Lead	3.83E-7	Inappropriate For Evaluation				--		
							3E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Benzo(a)anthracene	1.79E-8	7.3E-1	B2	Various	TEF*	1.3E-8		
Chrysene	2.73E-8	7.3E-3	B2	Various	TEF	2.0E-10		
Benzo(k)flouranthene	2.35E-8	7.3E-2	B2	Various	TEF	1.7E-9		
Benzo(b)flouranthene	2.94E-8	7.3E-1	B2	Various	TEF	2.2E-8		
Arsenic	1.38E-7	1.5E+0	A	Various	IRIS	2.1E-7		
Lead	7.64E-7	Inappropriate For Evaluation				--		
							2E-7	

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Table 2A-5. Continued

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]							3E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]							1E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1,2]							7E-8	
								6E-7

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 2-11.
* TEF = toxicity equivalency factor relative to benzo(a)pyrene (USEPA 1993b).

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Table 2A-6. Cancer Risk Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Benzo(a)anthracene	1.79E-8	7.3E-1	B2	Various	TEF*	1.3E-8		
Chrysene	2.73E-8	7.3E-3	B2	Various	TEF	2.0E-10		
Benzo(k)flouranthene	2.35E-8	7.3E-2	B2	Various	TEF	1.7E-9		
Benzo(b)flouranthene	2.94E-8	7.3E-1	B2	Various	TEF	2.2E-8		
Arsenic	1.38E-8	1.5E+0	A	Various	IRIS	2.1E-8		
Lead	7.64E-8	Inappropriate For Evaluation				--		
							6E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Benzo(a)anthracene	1.79E-8	7.3E-1	B2	Various	TEF*	1.3E-8		
Chrysene	2.73E-8	7.3E-3	B2	Various	TEF	2.0E-10		
Benzo(k)flouranthene	2.35E-8	7.3E-2	B2	Various	TEF	1.7E-9		
Benzo(b)flouranthene	2.94E-8	7.3E-1	B2	Various	TEF	2.2E-8		
Arsenic	1.38E-7	1.5E+0	A	Various	IRIS	2.1E-7		
Lead	7.64E-7	Inappropriate For Evaluation				--		
							2E-7	

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Table 2A-6. Continued

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]							3E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]							1E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1, 2]							7E-8	
								3E-7

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 2-12.
* TEF = toxicity equivalency factor relative to benzo(a)pyrene (USEPA 1993b).

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Table 2A-7. Hazard Index Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Benzo(b)fluoranthene	4.39E-6								
Benzo(k)fluoranthene	3.51E-6								
Benzo(g,h,i)perylene	2.06E-6								
Fluoranthene	8.70E-6	4E-2	Nephropathy	IRIS	3,000	1	2.2E-4		
Benzo(a)anthracene	2.67E-6								
Chrysene	4.07E-6								
Phenanthrene	4.31E-6	Under Review							
Pyrene	5.70E-6	3E-2	Kidney Effects	IRIS	3,000	1	1.9E-4		
Arsenic	2.07E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	3.61E-5	3.5E-3	Blood pressure	IRIS	3	1	1.0E-2		
Cadmium	2.03E-6	3E-4	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	1.79E-5	2.5E-4[2]	None given	IRIS	500	1	7.0E-2		
Nickel	3.52E-6	1.0E-3	Decreased weight	IRIS	300	1	3.5E-3		
Lead	1.14E-5	Inappropriate For Evaluation							
Aluminum	3.25E-3								
Cobalt	4.38E-6								
Copper	5.35E-6								
Manganese	9.90E-5	1E-2	CNS Effects	IRIS	1	1	1.0E-2		
Vanadium	8.85E-6	3.5E-4		HEAST			3.0E-2		
Zinc	1.13E-5	1.5E-2	ESOD Decrease	IRIS	3	1	7.5E-4	1E-1	

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Table 2A-7 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Benzo(b)fluoranthene	4.29E-7								
Benzo(k)flouranthene	3.43E-7								
Benzo(g,h,i)perylene	2.01E-7								
Fluoranthene	8.51E-7	4E-2	Nephropathy	IRIS	3,000	1	2.1E-5		
Benzo(a)anthracene	2.61E-7								
Chrysene	3.98E-7								
Phenanthrene	4.11E-7	Under Review							
Pyrene	5.57E-7	3E-2	Kidney Effects	IRIS	3,000	1	1.9E-5		
Arsenic	2.02E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	3.53E-5	7E-2	Blood pressure	IRIS	3	1	5.0E-4		
Cadmium	1.98E-6	1E-3	Proteinuria	IRIS	10	1	2.0E-3		
Chromium	1.75E-5	5E-3[2]	None given	IRIS	500	1	3.5E-3		
Nickel	3.44E-6	2E-2	Decreased weight	IRIS	300	1	1.7E-4		
Lead	1.11E-5	Inappropriate For Evaluation							
Aluminum	3.17E-3								
Cobalt	4.28E-6								
Copper	5.23E-6								
Manganese	9.68E-5	1.4E-1	CNS Effects	IRIS	1	1	6.9E-4		
Vanadium	8.66E-6	7E-3		HEAST			1.2E-3		
Zinc	1.11E-5	3.0E-1	ESOD Decrease	IRIS	3	1	3.7E-5	2E-2	

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Table 2A-7 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[3]								2E-4	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[3]								5E-6	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[3]								4E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[3]								2E-2	
Exposure Pathway: Ingestion of Groundwater[3]								2E-1	
									4E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Value for Chromium VI.
[3] See Table 2-13.

019000

Table 2A-8. Hazard Index Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Benzo(b)fluoranthene	8.59E-7								
Benzo(k)fluoranthene	6.86E-7								
Benzo(g,h,i)perylene	4.03E-7								
Fluoranthene	1.70E-6	4E-2	Nephropathy	IRIS	3,000	1	4.3E-5		
Benzo(a)anthracene	5.21E-7								
Chrysene	7.96E-7								
Phenanthrene	8.42E-7	Under Review							
Pyrene	1.11E-6	3E-2	Kidney Effects	IRIS	3,000	1	3.7E-5		
Arsenic	4.04E-7	3E-4	Hyperpigmentation	IRIS	3	1	1.4E-3		
Barium	7.06E-6	3.5E-3	Blood pressure	IRIS	3	1	2.0E-3		
Cadmium	3.96E-7	3E-4	Proteinuria	IRIS	10	1	1.3E-3		
Chromium	3.49E-6	2.5E-4[2]	None given	IRIS	500	1	1.0E-2		
Nickel	6.88E-7	1.0E-3	Decreased weight	IRIS	300	1	6.9E-4		
Lead	2.23E-6	Inappropriate For Evaluation							
Aluminum	6.35E-4								
Cobalt	8.57E-7								
Copper	1.05E-6								
Manganese	1.94E-5	1E-2	CNS Effects	IRIS	1	1	1.9E-3		
Vanadium	1.73E-6	3.5E-4		HEAST			4.9E-3		
Zinc	2.21E-6	1.5E-2	ESOD Decrease	IRIS	3	1	1.5E-4	2E-2	

019901

Table 2A-8 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Benzo(b)fluoranthene	4.29E-7								
Benzo(k)flouranthene	3.43E-7								
Benzo(g,h,i)perylene	2.01E-7								
Fluoranthene	8.51E-7	4E-2	Nephropathy	IRIS	3,000	1	2.1E-5		
Benzo(a)anthracene	2.61E-7								
Chrysene	3.98E-7								
Phenanthrene	4.11E-7	Under Review							
Pyrene	5.57E-7	3E-2	Kidney Effects	IRIS	3,000	1	1.9E-5		
Arsenic	2.02E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	3.53E-5	7E-2	Blood pressure	IRIS	3	1	5.0E-4		
Cadmium	1.98E-6	1E-3	Proteinuria	IRIS	10	1	2.0E-3		
Chromium	1.75E-5	5E-3[2]	None given	IRIS	500	1	3.5E-3		
Nickel	3.44E-6	2E-2	Decreased weight	IRIS	300	1	1.7E-4		
Lead	1.11E-5	Inappropriate For Evaluation							
Aluminum	3.17E-3								
Cobalt	4.28E-6								
Copper	5.23E-6								
Manganese	9.68E-5	1.4E-1	CNS Effects	IRIS	1	1	6.9E-4		
Vanadium	8.66E-6	7E-3		HEAST			1.2E-3		
Zinc	1.11E-5	3.0E-1	ESOD Decrease	IRIS	3	1	3.7E-5	2E-2	

019902

Table 2A-8 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[3]								2E-4	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[3]								5E-6	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[3]								4E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[3]								2E-2	
Exposure Pathway: Ingestion of Groundwater[3]								1E-1	
									2E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Value for Chromium VI.
[3] See Table 2-14.

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associated with exposure to PAHs detected at the site should be considered in evaluation of these estimates.

2A.5.3.2 Cancer Risk Estimates. Cancer risk estimates for future industrial land use are presented in Table 2A-9 and 2A-10 for RME and CTE, respectively. Similar to estimates for recreational land use, cancer risk for this scenario is driven by exposure to PAHs and arsenic at the site via dermal contact and arsenic via soil ingestion. Total exposure risk estimates of 5E-6 (RME) and 1E-6 (CTE) are slightly lower than or equal to original risk estimates for the site as a whole (Table 2-17). These estimates are well within the acceptable cancer risk range and do not indicate a concern for cancer-related health effects associated with future industrial use of this limited area of Site 1. With the exception of lead, toxicity values were available for all evaluated carcinogens, resulting in increased confidence in these estimates.

2A.5.4 Uncertainties Associated with Addendum Risk Estimates. Most areas of uncertainty associated with original risk estimates for Site 1 would be applicable to risk characterization for this addendum. These uncertainties are discussed in Section 2.5.4.

2A.5.5 Addendum Risk Summarization. Total risk estimates derived as a result of addendum sampling efforts are summarized in Table 2A-11. While these values are provided in the discussion above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline assessment for a limited potential "hot spot" area at LHAAP Site 1 do not indicate any unacceptable risk to human health associated with continued current or future industrial land uses in the absence of remediation.

2A.5.6 Addendum Conclusions. Objectives of this addendum to the original Site 1 baseline human health risk assessment were to conduct further supplemental risk characterization for a potential "hot spot" at the site, evaluate the similarity between concentrations of chemical constituents in 0- to 6-inch soil depth samples with those used in original risk estimates, and expand the list of evaluated metals. Results of these additional evaluations indicate a similarity between chemical constituents from the two soil depths and relative similarity between risk estimates (both cancer and non-cancer) for the limited area and the site as a whole. Based on the assumptions, approaches, methods, and uncertainties presented in this addendum, unacceptable risk to human receptors was not identified. As such, this addendum substantiates conclusions of the original assessment and fails to support the need for site remediation for protection of human health.

Table 2A-9. Cancer Risk Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Benzo(a)anthracene	9.33E-7	7.3E-1	B2	Various	TEF*	6.8E-7		
Chrysene	1.42E-6	7.3E-3	B2	Various	TEF	1.0E-8		
Benzo(k)flouranthene	1.23E-6	7.3E-2	B2	Various	TEF	9.0E-8		
Benzo(b)flouranthene	1.54E-6	7.3E-1	B2	Various	TEF	1.1E-6		
Arsenic	7.23E-7	1.5E+0	A	Various	IRIS	1.1E-6		
Lead	3.99E-6	Inappropriate For Evaluation				--	3E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Benzo(a)anthracene	9.27E-8	7.3E-1	B2	Various	TEF*	6.8E-8		
Chrysene	1.42E-7	7.3E-3	B2	Various	TEF	1.0E-9		
Benzo(k)flouranthene	1.22E.7	7.3E-2	B2	Various	TEF	8.9E-9		
Benzo(b)flouranthene	1.53E-7	7.3E-1	B2	Various	TEF	1.1E-7		
Arsenic	7.19E-7	1.5E+0	A	Various	IRIS	1.1E-6		
Lead	3.97E-6	Inappropriate For Evaluation				--	1E-6	

019906

Table 2A-9 Continued

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]							3E-8	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]							1E-10	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1, 2]							7E-7	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1, 2]							3E-10	
Exposure Pathway: Ingestion of Groundwater[2]							3E-9	
								5E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 2-15.
* TEF = toxicity equivalency factor relative to benzo(a)pyrene (USEPA 1993b).

019907

Table 2A-10. Cancer Risk Estimates, Site 1 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Benzo(a)anthracene	6.72E-8	7.3E-1	B2	Various	TEF*	4.9E-8		
Chrysene	1.03E-7	7.3E-3	B2	Various	TEF	7.5E-10		
Benzo(k)flouranthene	8.83E-8	7.3E-2	B2	Various	TEF	6.5E-9		
Benzo(b)flouranthene	1.11E-7	7.3E-1	B2	Various	TEF	8.1E-8		
Arsenic	5.20E-8	1.5E+0	A	Various	IRIS	7.8E-8		
Lead	2.87E-7	Inappropriate For Evaluation				--		
							2E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Benzo(a)anthracene	3.35E-8	7.3E-1	B2	Various	TEF*	2.5E-8		
Chrysene	5.12E-8	7.3E-3	B2	Various	TEF	3.7E-10		
Benzo(k)flouranthene	4.41E-8	7.3E-2	B2	Various	TEF	3.2E-9		
Benzo(b)flouranthene	5.52E-8	7.3E-1	B2	Various	TEF	4.0E-8		
Arsenic	2.60E-7	1.5E+0	A	Various	IRIS	3.9E-7		
Lead	1.43E-6	Inappropriate For Evaluation				--		
							5E-7	

019908

Table 2A-10. Continued

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Inhalation of Particulates[2]							1E-8	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]							4E-11	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1, 2]							3E-7	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1, 2]							1E-10	
Exposure Pathway: Ingestion of Groundwater[2]							8E-10	
								1E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 2-16.
* TEF = toxicity equivalency factor relative to benzo(a)pyrene (USEPA 1993b).

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Table 2A-11. Summary of Baseline Risk Estimates
Site 1 Addendum, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	6E-2	Chromium/Dermal Contact (Soil)
CTE	3E-2	Chromium/Dermal Contact (Soil & Water)
Cancer Risk		
RME	6E-7	PAH Compounds/Dermal Contact (Soil)
CTE	3E-7	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	4E-1	Chromium*/Groundwater Ingestion
CTE	2E-2	Chromium*/Groundwater Ingestion
Cancer Risk		
RME	5E-6	PAHs and Arsenic*/Dermal Contact (Soil)
CTE	1E-6	Arsenic*/Soil Ingestion

* All concentrations within LHAAP facility background range.

ECOLOGICAL ASSESSMENT

2.7 INTRODUCTION

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA 1992a). While a "stressor" may be any physical, chemical, or biological entity that induces adverse ecological response, chemicals are stressors most frequently evaluated at hazardous waste sites. This ecological assessment evaluates the potential for such response at LHAAP Site 1 (Inert Burning Grounds) and was prepared in accordance with general guidance provided in USEPA (1992a; 1994).

As described in Chapter 1 of this document, ecological evaluations for all LHAAP Group 1 sites were conducted as initial screening-level assessments. It should be re-emphasized that this type of assessment does not attempt to define actual site risks, but is used only to determine whether additional ecological evaluation is warranted at site. Assumptions, methods, and applicability of this type of assessment to LHAAP Site 1 are provided in this evaluation.

Remedial investigation sampling activities and results at Site 1 were presented as part of the human health evaluation earlier in this chapter. As these data also formed the basis for ecological assessment at the site, frequent reference is made to appropriate sections of the human health evaluation to prevent repetitive presentation of information applicable to both assessments.

2.8 PRELIMINARY PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

2.8.1 Environmental Setting. Site 1 is located in the extreme northwest corner of LHAAP near the intersection of Avenue P and 32nd Street (Figure 1-3). A map showing site topography, surface drainage patterns, suspected site limits, and other site features is presented in Figure 2-1. The site consists of approximately 5 acres of heavy timber and undergrowth that has been re-established since the site was last used during the 1960's. Site habitat can best be described as mixed pine/hardwood forest dominated by hardwoods such as sweetgum, hackberry, several hickory species, and a variety of oaks. Also present in the overstory are several species of pine. Groundcover vegetation consists partially of vines, such as greenbriar, poison ivy, honeysuckle, and ferns. A wide variety of terrestrial animals (Appendix A) common to upland forest habitat would be expected to inhabit the site.

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No permanent creeks or streams exist on Site 1, and surface water is limited to that conveyed for short periods following rainfall events in drainage ditches bordering the site. Local creeks and bayous are a considerable distance from the site (see Section 2.1.2).

2.8.2 Endangered and Threatened Species. A complete listing and discussion of endangered and threatened species at LHAAP and surrounding areas is presented in the species inventory report for the facility contained in Appendix A. A review of life histories and habitat requirements for these species indicates that most would not be expected to occur at Site 1. While several of these species might occasionally use or pass through habitat at the site, the area is not known to be of prime importance to or classified as critical habitat for any of these species. None of these species are known to inhabit the site. Accordingly, significant impacts on endangered or threatened species are not anticipated in association with LHAAP Site 1.

2.8.3 Contaminants of Potential Ecological Concern. Complete details of chemical sampling activities at Site 1 are presented in the Group 1 SCSR. These activities and results are summarized in section 2.2 of this chapter. Also detailed in this section of the human health assessment is the rationale for elimination of a limited number of chemicals as chemicals of concern. As the only basis for elimination of these chemicals was detection in blank samples, most detected constituents were retained for human health evaluation. In a similar manner, an identical set of chemicals was used in evaluating ecological effects.

In summary, detected chemicals at the site included several VOCs, a number of PAH compounds, and metals. A complete and specific list of chemicals of potential ecological concern is provided in later sections of this evaluation.

2.8.4 Site Conceptual Model for Ecological Exposure. Chemical data collected at Site 1 were evaluated in terms of potential exposure for ecological receptors. This resulted in formulation of a site-specific conceptual model for ecological exposure. Factors considered in this evaluation and the selected exposure model for Site 1 are presented below.

While low levels of limited contaminants (principally VOCs and metals) were detected in groundwater at Site 1 (Table 2-1), low levels of these constituents and considerable distances to surface water environments (described in section 2.1.2) preclude significant ecological exposure via groundwater recharge to these systems. In addition, low levels and infrequent detection of contaminants in site soils and drainage systems from the site, combined with distances to receiving waters, minimize the potential for contaminant loading to off-site aquatic systems via surface runoff. Finally, on-site surface waters are limited to those conveyed for short periods of time following rainfall events via site drainage swales and ditches. While these waters might provide brief exposure to terrestrial organisms, it is unlikely that wet/dry cycles associated with these ditches would allow establishment of permanent on-site aquatic communities. Accordingly, potential for ecological exposure to both on- and off-site aquatic receptors was considered minimal for this site, and emphasis was focused on exposure to terrestrial organisms.

Owing to the presence of chemicals of ecological concern in site soils, potential for exposure of terrestrial organisms to these contaminants via soil ingestion, direct contact, and ingestion of potentially-contaminated prey items was evaluated for this assessment. While direct contact (dermal exposure) was not evaluated for this screening-level assessment, exposure via soil and prey ingestion was considered potentially significant. While a number of exposure scenarios involving different organisms are conceivable, maximum exposure would be expected for organisms with high prey (and associated soil) ingestion rates. As these pathways were considered most significant (and most conservative) for the site, a site conceptual model involving soil and prey ingestion for terrestrial organisms became the focus for the LHAAP Site 1 ecological assessment. For these reasons, feeding guilds represented by the least shrew and woodcock models described in Chapter 1 were evaluated for the site.

2.8.5 Screening-Level Ecotoxicity Values. Following development of a site conceptual exposure model, the next step in the screening-level ecological assessment is development of screening ecotoxicity values for chemicals of concern (USEPA 1994). As these values have not currently been tabulated for ecological effects (in a format similar to IRIS for human health assessments), this generally results in a literature search, evaluation of studies appropriate for exposure pathways and receptor species under consideration, and use of professional judgement in deriving chemical-specific toxicity values. Methodology used in developing screening-level toxicity values for LHAAP Site 1 (and all Group 1 sites) is described below. These methods followed, as closely as possible, general guidelines provided in USEPA (1994).

For each evaluated exposure route and species, scientific literature was reviewed for the highest exposure level shown to produce no adverse effects (e.g., reduced growth, impaired reproduction, increased mortality) in species closely related to those under evaluation as recommended in USEPA (1994). Toxicity information was obtained from a variety of literature sources with the search facilitated by query of toxicity data bases, including Toxline, Registry of Toxic Effects of Chemical Substances (RTECS), Chemical Abstracts (CA Service), Integrated Risk Information System (IRIS), and Hazardous Substances Data Base (HSDB).

In evaluating toxicity data, no-observed-adverse-effects-levels (NOAELs) were preferentially obtained over lowest-observed-adverse-effect-levels (LOAEL) values owing to their suitability for use in conservative screening-level evaluation (USEPA 1994). In addition, toxicity data for chronic effects were preferentially obtained, when available, over those for acute exposure. Diet-based toxicity data were converted to daily doses (mg/Kg body weight/day) using intake data presented in these studies or information on average ingestion rates and body weights of test animals. As exposure routes for this assessment involved oral ingestion, studies based on this route of exposure were evaluated prior to consideration of those involving exposure via gavage or subcutaneous injection.

Where chronic NOAEL doses were unavailable for given chemicals and test species, these values were estimated by applying appropriate extrapolation factors to toxicity data based on LOAELs and/or acute exposure. Weil and McCollister (1963) examined ratios of LOAELs to NOAELs from chronic and subchronic studies. Their analysis showed ratios were less than or equal to five (5) in 50 of 52 (96%) paired comparisons. Accordingly, an extrapolation factor of five (5) was used to convert LOAEL values to NOAELs. Additionally, an extrapolation factor of five (5) was used to extrapolate acute to chronic exposure-based values. Both types of conversions were necessary for only a limited number of chemicals, as most obtained values were based on chronic NOAELs.

Reference toxicity values (RTVs) obtained using the above methodology for both small mammal and avian toxicity evaluations are contained in Appendix C. Included with these values are the evaluated species, duration of experimental exposure, critical effects, and referenced study. Extrapolation factors (as described above) were applied to listed values not based on chronic NOAELs. For mammalian evaluation, values were obtained or estimated for most chemicals of concern. While a value was obtained for benzo(a)pyrene, values for other PAHs were lacking. Therefore, the RTV for benzo(a)pyrene was applied to all other PAHs in screening risk estimation. While data were available for most metals for avian toxicity, values were not available in the literature for several organics (most notably PAHs). A lack of toxicity information for some chemicals for both vertebrate groups should be considered an area of uncertainty for this assessment.

2.9 PRELIMINARY EXPOSURE ESTIMATE AND RISK CALCULATION

2.9.1 General. Estimation of exposure and risk calculation comprise the second step in ecological risk screening for a site. Screening-level risk estimates are obtained by comparing maximum conservative exposure levels with ecotoxicity values for species under evaluation (USEPA 1994). This evaluation conducted for LHAAP Site 1 is presented below.

2.9.2 Preliminary Exposure Estimate. Conservative exposure estimates (doses) for both the least shrew and the American woodcock for Site 1 were obtained using equations and parameter values presented in Chapter 1 of this document. As a further means of providing conservatism to intake estimates, maximum detected concentrations of all COPC in site soils and drainage ditch surface "sediments" were used in dose estimation. As noted in the human health evaluation for this site, drainage ditch soils are dry most of the time. Accordingly, these areas provide a potential source of exposure to ecological receptors in a manner similar to soils. In addition, data obtained for soil samples to a depth of five (5) feet below ground surface were evaluated for use in dose estimation. This depth range was used to account for possible exposure to deep burrowing animals and to provide for ecological risk estimation for potential exposure to subsurface soils should they be exposed through site activities under a future industrial land use scenario (as described in the human health assessment). Accordingly, chemical concentrations used in intake estimations were maximum values from Tables 2-2 and 2-4.

As noted in this chapter, screening dose estimates are based on conservative assumptions and parameter values. Resulting intake estimates for soil and prey ingestion for both model species are presented in the next section of this assessment.

2.9.3 Preliminary Risk Calculation. Although several approaches may be used, the hazard quotient method comparing single effect and exposure values is adequate for screening-level risk estimation (USEPA 1994). This method compares estimated exposure levels to measured or predicted threshold value for effects (RTVs as developed above). This method was used for screening-level assessment for LHAAP Site 1.

Ecological screening risk estimates derived for Site 1 least shrew and woodcock models are presented in Tables 2-18 and 2-19, respectively. Screening hazard quotients developed for each chemical of concern and species were examined for relative contribution to overall screening risk. Hazard quotients approaching or exceeding unity (1.0) received close scrutiny for ecological concern and potential further ecological evaluation.

The overall screening HI for the least shrew model for LHAAP Site 1 was estimated at 2E+1 (Table 2-18). Chemicals contributing the majority of this risk consisted entirely of metals and included antimony, chromium, lead, and nickel with screening hazard quotients of 2E+0, 1E+1, 3E+0, and 4E+0, respectively. Accordingly, further consideration was given to interpretation of these results. Contribution of organics (including PAHs) present at Site 1 to the overall screening HI was negligible, with hazard quotients for all organics totaling 1E-2 for the least shrew model.

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Table 2-18. Ecological Screening Risk Estimate For Least Shrew Model, Site 1, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value[1] (mg/Kg-day)	Screening Hazard Quotient
2-Butanone	6.2E-4	NA	6.2E-4	1771	4E-7
Acetone	1.6E-2	NA	1.6E-2	900	2E-5
Methylene Chloride	5.2E-4	NA	5.2E-4	185	3E-6
Toluene	2.3E-4	NA	2.3E-4	22	1E-5
Xylene	8.0E-4	NA	8.0E-4	NA	NA
Bis(2-ethylhexyl)phthalate	4.4E-2	NA	4.4E-2	13	3E-3
Benzoic Acid	7.0E-2	NA	7.0E-2	500	1E-4
Phenanthrene	2.8E-2	7.4E-2	1.0E-1	130[2]	8E-4
Flouranthene	4.2E-2	1.5E-1	1.9E-1	130[2]	1E-3
Pyrene	4.5E-2	1.7E-1	2.2E-1	130[2]	2E-3
Benzo(a)anthracene	2.0E-2	5.1E-2	7.1E-2	130[2]	6E-4
Chrysene	1.4E-2	6.1E-2	7.5E-2	130[2]	6E-4
Benzo(k)flouranthene	2.0E-2	4.0E-2	6.0E-2	130[2]	5E-4
Benzo(b)flouranthene	2.3E-2	4.7E-2	7.0E-2	130[2]	5E-4
Benzo(a)pyrene	2.2E-2	7.0E-2	9.2E-2	130[2]	7E-4
Ideno(1,2,3-cd)pyrene	1.5E-2	5.7E-2	7.2E-2	130[2]	6E-4
Dibenzo(a,h)anthracene	1.5E-3	7.2E-3	8.7E-3	130[2]	7E-5
Benzo(g,h,i)perylene	1.3E-2	1.8E-2	3.1E-2	130[2]	2E-4
Antimony	2.6E-1	NA	2.6E-1	0.14	2E+0
Arsenic	2.3E-1	1.1E-1	3.4E-1	3.63	9E-2
Barium	4.9E+0	1.7E+1	6.6E+0	82.9	8E-2
Chromium	8.3E-1	6.2E+0	7.0E+0	0.56	1E+1
Lead	2.0E+0	9.9E+0	1.2E+1	4.6	3E+0
Mercury	3.9E-3	1.4E-2	1.8E-2	31.5	6E-4
Nickel	6.0E-1	1.0E+1	1.1E+1	2.5	4E+0
Selenium	2.9E-2	NA	2.9E-2	0.375	8E-2
Silver	2.6E-2	NA	2.6E-2	20	1E-3
				Screening Hazard Index -	2E+1

[1] See Appendix C. [2] Based on value for benzo(a)pyrene. NA = Not available.

Table 2-19. Ecological Screening Risk Estimate For American Woodcock Model
Site 1, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
2-Butanone	8.9E-4	NA	8.9E-4	NA	NA
Acetone	2.2E-2	NA	NA	2.8E+3	NA
Methylene Chloride	7.4E-4	NA	7.4E-4	NA	NA
Toluene	3.3E-4	NA	3.3E-4	NA	NA
Xylene	1.1E-3	NA	1.1E-3	389	3E-6
Bis(2-ethylhexyl)phthalate	6.3E-2	NA	6.3E-2	11.3	6E-3
Benzoic Acid	1.0E-1	NA	1.0E-1	NA	NA
Phenanthrene	3.9E-2	1.1E-1	1.5E-1	NA	NA
Flouranthene	6.0E-2	2.1E-1	2.7E-1	NA	NA
Pyrene	6.4E-2	2.4E-1	3.0E-1	NA	NA
Benzo(a)anthracene	2.8E-2	7.2E-2	1.0E-1	NA	NA
Chrysene	2.0E-2	8.6E-2	1.1E-1	NA	NA
Benzo(k)flouranthene	2.8E-2	5.7E-2	8.5E-2	NA	NA
Benzo(b)flouranthene	3.3E-2	6.6E-2	9.9E-2	NA	NA
Benzo(a)pyrene	3.1E-2	1.0E-1	1.3E-1	NA	NA
Ideno(1,2,3-cd)pyrene	2.1E-2	8.2E-2	1.0E-1	NA	NA
Dibenzo(a,h)anthracene	2.2E-3	1.0E-2	1.2E-2	NA	NA
Benzo(g,h,i)perylene	1.8E-2	2.6E-2	4.4E-2	NA	NA
Antimony	3.8E-1	NA	3.8E-1	NA	NA
Arsenic	3.3E-1	1.5E-1	4.8E-1	28.9	2E-2
Barium	7.0E+0	2.4E+1	3.1E+1	NA	NA
Chromium	1.2E+0	8.8E+0	1.0E+1	95	1E-1
Lead	2.8E+0	1.4E+1	1.7E+1	26	6E-1
Mercury	5.6E-3	1.9E-2	2.5E-2	0.179	1E-1
Nickel	8.5E-1	1.5E+1	1.6E+1	16.9	9E-1
Selenium	4.1E-2	NA	4.1E-2	0.49	8E-2
Silver	3.7E-2	NA	3.7E-2	17.2	2E-3
				Screening Hazard Index -	2E+0

* See Appendix C. NA = Not available.

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The overall screening HI for the American woodcock evaluation was estimated at 2E+0. While no chemical-specific hazard quotient exceeded unity, those for lead (6E-1) and nickel (9E-1) approached this critical value and constituted the majority of overall screening-level risk. Accordingly, further consideration was given to interpretation of these results. Avian toxicity data were not available for many organics (most notably PAHs) and should be considered an area of uncertainty for these estimates.

In summary, screening-level risk calculations for both the least shrew and woodcock models indicated that further interpretation of results for several metals was warranted for LHAAP Site 1. Collectively, these metals included antimony, chromium, lead, and nickel. Screening risk estimates for organics present in site soils were extremely low and indicative of little or no ecological risk.

2.9.4 Evaluation of Chemicals Driving Screening-Level Risk Estimates. Given the identification of antimony, chromium, lead, and nickel as metals driving screening-level risk estimates at LHAAP Site 1, data for these constituents were further evaluated for this assessment. While not initially employed in selection of COPC for the site, this further evaluation first involved comparison with background concentrations for these metals. This evaluation provided a measure of the relative contribution of background metals to overall screening-level risk for the site. As site soils data to a depth of five (5) feet below ground surface were used for this assessment, background values for both surface and subsurface soils (USACE 1995b) were used in this evaluation. A comparison of UCLs of concentrations of these metals in site soils relative to background UCLs is presented in Table 2-20. This approach was used to facilitate comparison of reasonable exposure-relevant metals concentrations for the site with those in background soils.

Table 2-20. Comparison of 95% Upper Confidence Limits (UCL) of Selected Metals in Soils - Site 1 Versus Background. All values are mg/Kg.

Metal	Site 1 95% UCL[1]	Background 95% UCL	
		Surface[2]	Subsurface[3]
Antimony	0.66	7.5	7.5
Chromium	15.23	16.7	14.5
Lead	12.95	14.6	6.3
Nickel	7.19	4.8	8.6

[1] All soil depths to 5 feet (compare with Table 2-7).
[2] 0- to 6-inch depth (USACE 1995b).
[3] >6-inch depth (USACE 1995b).

A comparison of UCLs for these selected metals at Site 1 reveals that all four metals are present at concentrations approximating background levels (Table 2-20). Accordingly, screening-level ecological risks calculated for the site are driven by constituents present at naturally-occurring concentrations for the facility. These data fail to support evidence of a chemical release of these metals at the site, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, these metals were eliminated from further ecological evaluation at Site 1.

2.9.5 Uncertainties. Evaluation of these screening-level ecological assessment results should include consideration of areas and degrees of uncertainty associated with risk estimates (USEPA 1994). While every attempt was made to minimize areas of uncertainty with the use of conservative assumptions and estimation techniques, numerous areas of uncertainty remain and should be considered in site-related decisions. Areas of uncertainty associated with chemical sampling and analysis at Site 1 were presented in the human health evaluation (Table 2-8) and would be equally applicable to use of these data for ecological evaluation. Several additional areas of uncertainty specific to ecological evaluation are described below.

Despite the use of conservative risk estimation techniques, it is always possible that species with unknown, yet elevated sensitivities to certain chemical constituents may exist at a site. It is therefore possible that risk estimation methods may underestimate chemical-related risks for these species.

Another area of uncertainty for ecological assessment always involves use of laboratory dose-response data for estimation of ecological effects on indigenous species at a site. Uncertainties associated with use of these data are further increased by the use of a variety of safety or correction factors used to extrapolate types and degrees of biological response (e.g., chronic versus subchronic effects). Finally, the lack of toxicity data for some chemicals under evaluation often adds to uncertainty for ecological assessment. While conservative assumptions are frequently used in an attempt to mitigate these factors, these areas of uncertainty remain and should be considered in site-related decisions.

2.10 SUMMARY

A screening-level ecological risk assessment was prepared to support site management decisions for LHAAP Site 1 (Inert Burning Grounds). The assessment represents a conservative estimate of the potential for ecological concerns at the site and the resulting need (or lack thereof) for further ecological evaluations to support site management decisions. The assessment was conducted based on a site conceptual model of terrestrial organism exposure (using both small mammal and avian species models) to COPC in site soils.

Based on methodology used in this assessment, four (4) metals (antimony, chromium, lead, and nickel) were identified as main contributors to screening-level risk estimates. Further evaluation of data for Site 1 revealed that these metals exist at concentrations approximating background levels for the facility. Accordingly, these data fail to support evidence of a chemical release of these metals to site soils, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, it is the conclusion of this screening-level assessment that little or no ecological concerns are associated with LHAAP Site 1, and that further ecological evaluations and remediation are unwarranted.

CHAPTER 3
LHAAP SITE 11
(SUSPECTED TNT BURIAL SITE)

HUMAN HEALTH EVALUATION

3.1 SITE DESCRIPTION

3.1.1 Site History. The Suspected TNT Burial Site (LHAAP Site 11) is an undocumented location where it is suspected that disposal of bulk TNT may have occurred during the 1940's. Other than the designation of this location during early site identification activities at LHAAP, there is no confirmed documentation that TNT burial ever occurred at the site. The site has been inactive since its suspected use in the 1940's.

3.1.2 Site Location and Features. Site 11 covers an area of approximately 4 acres and is located in the undeveloped central portion of LHAAP immediately north of the intersection of Avenues P and Q (Figure 1-3). A map showing site topography, suspected site limits, and other site features is presented later in this chapter. The site consists of a relatively flat area of grass immediately north of the intersection. This area is bounded by Avenue P on the west, Avenue Q on the south, and a tree line to the north and east. Power lines parallel Avenues P and Q on two sides of the site. A large forested area extending to Central Creek (located approximately 0.2 miles north of the site) is present at the northern site boundary. Surface drainage from the area flows to ditches along eastern and western edges of the site, eventually draining to Central Creek. A borrow pit exists north of the site.

Geology and hydrogeology at Site 11 are described in detail in the Group 1 SCSR. In summary, surficial soils encountered across the site consisted of silty clays or clayey sands extending to depths of 6 to 14 feet below ground surface. Groundwater was first encountered at the site at depths ranging from approximately 9 to 24 feet below ground surface. Generally, groundwater was encountered within silty fine sand lenses contained within the thicker silt and clay layers. Monitoring wells were installed with their screens set across these sand lenses. A hydraulic gradient of 0.1 feet/feet in a due north direction was calculated for the site with horizontal groundwater flow velocity estimated at 0.72 feet/day.

3.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

3.2.1 Remedial Investigation Activities. In 1993, phase 1 remedial investigations were conducted at Site 11 by Ebasco Services, Inc. (Ebasco). Phase 2 sampling activities were conducted at the site by Sverdrup Environmental, Inc. (Sverdrup) in 1994. All information pertaining to sampling methods, boring logs, well diagrams, geotechnical data, survey information, and analytical data are provided in the Group 1 SCSR. While appropriate sections of the SCSR should be consulted for specific details, sampling activities pertinent to this baseline risk assessment are briefly summarized below.

In 1993, Ebasco collected twenty (20) soil samples and six (6) groundwater grab samples from six (6) soil borings at LHAAP Site 11. As the suspected source of contamination was believed to be buried explosives, uppermost soil samples were collected at depths of 0-2 to 0-4 (one location) feet below ground surface. Phase 1 sampling also included collection of two (2) surficial (0- to 6-inch depth) ditch "sediment" and surface water samples. All samples of all environmental media collected during phase 1 efforts were analyzed for VOCs (EPA Method 8240); SVOCs (EPA Method 8270); explosives (EPA Method 8330); total metals, including silver, barium, cadmium, chromium, nickel, and antimony (EPA Method 6010); arsenic (EPA Method 7060); mercury (EPA Method 7470); lead (EPA Method 7421); selenium (EPA Method 7740); and thallium (EPA Method 7841), as well as selected anions.

In 1994, Sverdrup conducted phase 2 sampling at LHAAP Site 11. Sampling efforts included the installation and sampling of three (3) groundwater monitoring wells screened in the shallow water-bearing transmissive unit beneath the site. Thirteen (13) soil samples were collected during installation of these wells with uppermost samples collected at depths of 0 to 2 and 3 to 5 feet below ground surface. All samples were analyzed for parameters identical to those for phase 1. All phase 1 and phase 2 sampling locations, well locations, and other pertinent site information are shown in Figure 3-1.

3.2.2 Remedial Investigation Results. Complete results of all remedial investigation sampling activities are provided in detail in the Group 1 SCSR. Results forming the basis for this risk assessment are summarized below.

Constituents detected in groundwater at LHAAP Site 11 are summarized in Table 3-1. No volatile or semivolatile organics or explosives were detected in groundwater samples. Detected metals included barium, chromium, lead, and nickel. All detected concentrations of metals were well within background ranges established for LHAAP groundwater (Table 3-1). While lead has no established drinking water MCL, detected concentrations of barium, chromium, and nickel were well below MCLs for these metals (2, 0.1, and 0.1 mg/l, respectively).

Chemicals detected in Site 11 soil samples at depths relevant to risk assessment evaluations are summarized in Table 3-2. This summary includes all soil samples collected at the site to a depth of five (5) feet below ground surface. This depth range is included as it was used in risk estimation for future land use scenarios for the site (explained later in this text). No semivolatile organic or explosive compounds were detected in site soils. Detected organics included low levels (17 to 23 ug/Kg) of methylene chloride in soil samples collected during installation of monitoring wells 11WW02 and 11WW03 (Figure 3-1). While this VOC is a common laboratory contaminant (USEPA 1989), methylene chloride was not reported in blank samples for this sampling event. Eight (8) metals were detected in soil samples (Table 3-2). With the exception

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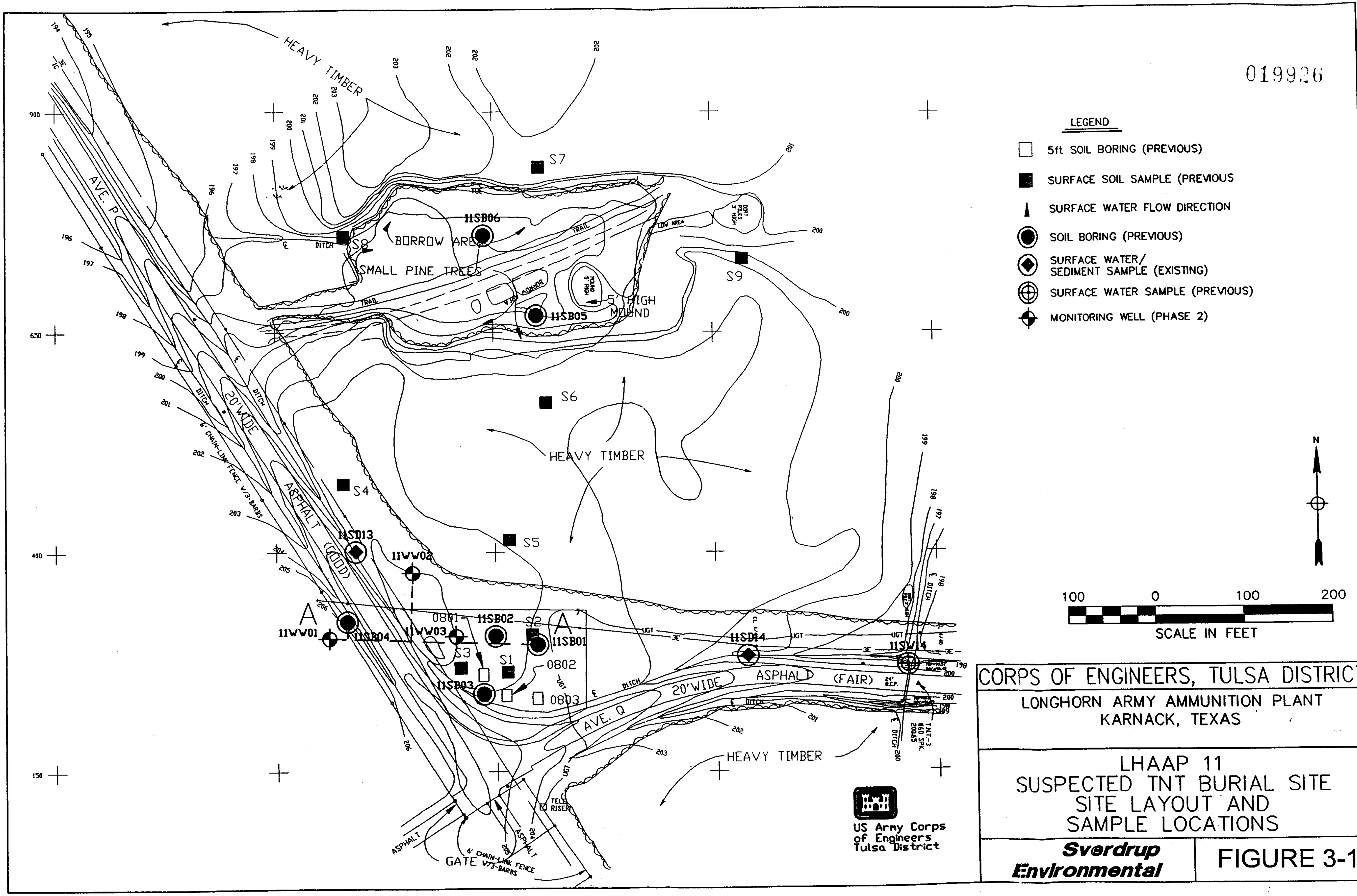

CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

LHAAP 11
SUSPECTED TNT BURIAL SITE
SITE LAYOUT AND
SAMPLE LOCATIONS

Sverdrup Environmental

FIGURE 3-1

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Table 3-1. Chemicals Detected in Groundwater Site 11, Longhorn Army Ammunition Plant				
Chemical	Frequency of Detection	Sample Quantitation Limits (mg/l)	Range of Detected Concentrations (mg/l)	Background Range* (mg/l)
Barium	3/3	--	0.032-0.3	0.02-1.99
Chromium	2/3	0.01	0.037-0.049	0.01-0.11
Lead	2/3	0.002	0.008-0.016	0.003-0.3
Nickel	2/3	0.04	0.047-0.051	0.02-0.06

* Range of detected concentrations from Final Groundwater Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Table 3-2. Chemicals Detected in Soils[1] Site 11, Longhorn Army Ammunition Plant				
Chemical	Frequency of Detection[2]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[3]
Organics (ug/Kg)				
Methylene Chloride	4/13	5-12	17-23	--
Metals (mg/Kg)				
Arsenic	13/13	--	2-9.7	1.7-36.8
Barium	13/13	--	25.8-167	22-287
Chromium	13/13	--	1.4-18.5	3.2-26.2
Lead	13/13	--	4.0-22	1.0-17.4
Mercury	5/13	0.01-0.11	0.01-0.02	0.25
Nickel	13/13	--	1.5-9.6	1.5-19.1
Selenium	4/13	0.1-2.3	0.2-2.3	0.5
Thallium	1/13	0.2-1.1	0.2	7.5

[1] Includes all soil samples to depth of 5 feet.
[2] Includes quality control duplicate samples.
[3] Range of detected concentrations of both surface (0-0.5 feet) and subsurface (>0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

of single reported concentrations of lead (22 mg/Kg in 11SB06) and selenium (2.3 mg/Kg in 11SB03), all detected metals were within background ranges for the facility.

Chemicals detected in Site 11 surface waters and ditch sediments are summarized in Table 3-3. No volatile or semivolatile organic compounds or explosives were detected in either medium. Only barium and lead were detected at low concentrations in surface water, and all metals concentrations in ditch sediments were within background ranges for LHAAP surface soils. These data indicate a lack of accumulation or concentration of contaminants in site ditches and a corresponding low potential for off-site transport of contaminants.

A review of data collected during all remedial investigations at LHAAP Site 11 reveals that the site possesses extremely low levels (if any) of contamination, and evidence of a chemical release at the site is questionable. However, due to detection of low levels of methylene chloride in two soil borings (without associated blank contamination) and single detections of two metals exceeding background ranges in site soils, risk evaluations were performed for the site.

3.2.3 Selection of Chemicals of Potential Concern. Environmental data sets described above were evaluated for selection of chemicals for use in quantitative risk assessment. Selection of chemicals was based on rationale described in Chapter 5 of RAGS/HHEM and discussed in Chapter 1 of this document.

Section 5.5 of RAGS/HHEM states that, under certain conditions, chemicals of concern may be eliminated based on comparison with concentrations in blank samples. Concentrations of all detected chemicals at Site 11 were below sample quantitation limits (SQLs) in all blank samples. Therefore, no chemicals were eliminated as COPC using this protocol. While most detected chemicals were reported at levels approximating background concentrations, all detected chemicals were retained as COPC for evaluation of total cumulative risk at the site (as described in Chapter 1). Accordingly, all detected constituents listed in Tables 3-1 through 3-3 were evaluated for quantitative risk analysis.

Table 3-3. Chemicals Detected in Surface Water and Ditch Surface Sediments
Site 11, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range*
Surface Water (mg/l)				
Barium	2/2	--	0.17-0.18	--
Lead	1/2	0.005	0.011	--
Ditch Sediments (mg/Kg)				
Arsenic	2/2	--	1.5-3.9	2.3-29.7
Barium	2/2	--	33.5-41.7	35.1-287
Chromium	2/2	--	8.1-20.9	3.2-22.8
Lead	2/2	--	4.0-13	2.6-17.4
Mercury	2/2	--	0.02	0.25
Nickel	2/2	--	2.7-3.1	1.5-6.3
Selenium	2/2	--	0.2-0.3	0.5

* Provided for comparison - range of detected concentrations in surface soils (0-0.5-foot depth) from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

3.3 EXPOSURE ASSESSMENT

3.3.1 Characterization of Exposure Setting. Site 11 at LHAAP is located in a relatively undeveloped portion of the plant. Work activities associated with LHAAP's mission are far removed from this location, and the only consistent activity near the site is vehicular traffic passing through the area. The site is also a considerable distance from the plant boundary or other areas of activity resulting in minimal potential for exposure for off-site receptors.

3.3.2 Identification of Exposure Pathways. Necessary elements of an exposure pathway include a source of contamination, transport medium, routes of exposure, and human receptors at exposure points (USEPA 1989). Absence of necessary elements results in incomplete exposure pathways indicating that exposure will not occur and no adverse impacts on human health exist for that pathway.

Exposure pathways considered for evaluation for this baseline risk assessment are listed in Table 3-4. Given existing land use and activities at the site, the only conceivable current land use exposure scenario would involve recreational use of the area. While even this is extremely limited at present, occasional deer hunting (during season weekends) is allowed at LHAAP and could result in limited use of the area. Even this scenario is questionable for Site 11 due to its proximity to paved roads and vehicular traffic. However, it is possible that the area could be frequented by an occasional hiker, bird-watcher, or other recreationist, although current security measures at the plant preclude unlimited public access to these areas. In light of the possibility of limited current recreational activities at the site, an exposure scenario involving recreational use of the area was evaluated for this assessment.

Exposure pathways under current recreational land use could include dermal contact with site soils and ditch surface sediments, incidental ingestion of surficial soils, inhalation of soil particulates, and inhalation of organic vapors released from soils (given limited detection of VOCs at the site). While on-site surface waters are confined to drainage ditches along roads containing water after rainfall events, dermal contact with these waters through wading is conceivable and was evaluated for this assessment. As these waters are of insufficient depth for swimming, the potential for ingestion of surface waters while swimming was considered low and was therefore not evaluated for this site.

Table 3-4. Summary of Exposure Pathways
Site 11, Longhorn Army Ammunition Plant

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
CURRENT LAND USE			
Plant Workers	Various	No	No current work activities at or near site. Pathway is incomplete.
Off-Plant Residents, Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Dermal contact with surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Incidental ingestion of surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of vapors from soils and ditches	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of soil and ditch particulates	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Dermal contact with surface waters	Yes	Potential recreational activities at site. Short-term presence of surface waters. Pathway potentially complete.
On-Site Recreationists	Ingestion of surface waters	No	No on-site surface water of depth suitable for swimming. Pathway incomplete.
FUTURE LAND USE			
Off-Plant Residents/ Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Various as listed under current land use	Yes	Potential future recreational activities at site. Pathways potentially complete.

Table 3-4 (Continued)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
FUTURE LAND USE (Continued)			
On-Site Workers	Dermal contact with surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Incidental ingestion of surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of organic vapors from soils and ditches	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of surface and subsurface soil and ditch sediment particulates	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Dermal contact with surface waters	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Ingestion of surface waters	No	No conceivable activities completing this pathway.
On-Site Workers	Ingestion of groundwater from on-site well	Yes	New well installation conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Dermal contact with groundwater	Yes	Showering conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Inhalation of volatiles from groundwater	No	No volatile compounds detected in groundwater.
On-Site Residents	Various	No	Residential land use not conceivable. Excessed property based on availability and/or remediation to industrial use standards.

While future land use practices at the site could include continued recreational use, future industrial development of the area is also conceivable. This scenario could occur as a result of construction required for mission changes at LHAAP or lease or excess of lands for industrial development. Industrial land use could potentially include excavation of site soils for construction purposes, other earth-moving activities, and maintenance functions resulting in exposure to industrial workers. This land use scenario may be more likely for Site 11 than other Group 1 sites given proximity of the site to access roads.

While exposure factors (i.e., exposure duration and frequencies) would most likely differ, exposure pathways under a future industrial land use scenario could include all those described above for recreational use. Despite the existence of a current water supply source at LHAAP, it is also plausible that an on-site water supply well could be installed at the site if industrial development were to occur. This would result in the additional exposure pathways of groundwater ingestion and dermal contact with groundwater (primarily through showering) for industrial site workers. As such, these pathways were evaluated under future industrial land use conditions.

Exposed populations for all land use scenarios were assumed to be composed entirely of adults, with no sensitive subpopulations (children, elderly, etc.) present on-site. As current recreational use at the site is primarily limited to deer hunting, small children would most likely not participate in these activities. Likewise, children would not be expected at the site under a future industrial scenario. As such, risk evaluations for this assessment were conducted for adult populations only.

3.3.3 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

3.3.3.1 Summary of Exposure Concentrations. Estimates of exposure concentrations for all environmental media and exposure pathways were developed using methodology described in Chapter 1 of this report. A brief explanation of rationale used in estimating exposure concentrations for pathways involving site soils is provided below.

For purposes of exposure estimation, surface soil is generally defined as the shallowest depth that can be practically sampled (i.e., 6 inches or 1 foot) (USEPA 1989; Region VI Supplemental Guidance). As initial soil sampling conducted at LHAAP Site 11 was conducted to investigate the nature and extent of potential contamination from explosives wastes which were reportedly buried, soil samples of surficial materials were initially collected at depths from 0 to 2 feet (0 to 4 feet at one location) (phase1) and 0 to 2 and 3 to 5 feet below ground surface (phase 2). Samples from depositional areas of drainage ditches were collected at depths of 0 to 6 inches below ground surface as an indication of potential transport of surface contaminants from site soils. Due to a lack of detected contaminants using this approach, extensive sampling of shallower layers was not conducted during phase 2 at the site. As a result, most "surface" soils data for this site were obtained from the 0- to 2-foot range. Use of these data for surface soil exposure concentration estimates adds some degree of uncertainty to these estimates, but is not considered a significant deficiency given site conditions.

Another consideration involves the use of surface materials collected from site drainage ditches in exposure estimates. These ditches represent shallow drainage pathways bordering the site which generally contain water for a short time only after rainfall events. While the term "sediment" has been applied to samples from these shallow ditches, from an exposure standpoint these surficial materials are similar to site soils in that they provide a source for volatilization of vapors (if present) and release of particulates and also serve as areas of potential exposure via ingestion and dermal contact. As the underlying basis for exposure at a site involves the use of spatially averaged soil concentrations contacted over time (USEPA 1992b), these ditches represent areas of potential soils exposure that should be accounted for in exposure estimates based on spatial averages. For these reasons, data obtained from ditches were combined with those from site soils for all pathways involving direct or indirect (through inhalation) exposure. The fact that these data are based on soil depths of 0 to 6 inches may also partially mitigate uncertainties associated with use of soils samples collected at slightly deeper depths when combined with these data for purposes of surface soil exposure estimation.

Based on rationale presented above, estimation of exposure concentrations involving site soils under current recreational land use were obtained by applying principles presented in Chapter 1 to soils data from uppermost sampling intervals in site soils and surficial ditch sediments. Estimated exposure concentrations for all site media for the current recreational land use scenario are presented in Table 3-5.

As future industrial land use could potentially involve soil excavation and earth-moving activities, the potential exists for exposure to soils at greater depths under this scenario. Accordingly, soils data from 3- to 5- foot depths were incorporated into these exposure estimates. Concentrations from 0- to 2 and 3- to 5- foot depths (when present) from each soil boring were averaged to obtain a single point estimate over a 5-foot depth for that boring. These values were then combined with ditches data and exposure estimates based on the 95% UCL calculated. Exposure concentration estimates for all pathways under the future industrial land use scenario are presented in Table 3-6.

3.3.3.2 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations presented in Chapter 1. All intake equations and variable values used in intake estimates for varying exposure scenarios were presented in this chapter.

Table 3-5. Summary of Exposure Concentrations, **Current Land Use**
Site 11, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Methylene Chloride	0.011	Concentrations are the 95% upper confidence limits or average concentrations in site surface soils and ditches assuming lognormal data distributions.
Arsenic	4.17	
Barium	110.22	
Chromium	14.27	
Lead	11.44	
Mercury	0.02*	
Nickel	6.90	
Selenium	2.12	
Thallium	0.2*	
Recreationists **Dermal contact with surface water**		
	mg/l	
Barium	0.18	Concentrations are maximum detected concentrations in on-site surface waters.
Lead	0.011	

* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).

Note: Soil data from 0-5-foot depth used in organic vapor inhalation exposure calculations (see Table 3-6).

Table 3-6. Summary of Exposure Concentrations, **Future Land Use**
Site 11, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists		
All exposure pathways	Same as listed in Table 3-5 (Current Land Use)	
Industrial Workers		
Incidental ingestion of soil **Dermal contact with soil** **Inhalation of particulates** **Inhalation of organic vapors**		
	mg/Kg	
Methylene Chloride	0.012	Concentrations are the 95% upper confidence limit or average concentrations of ditch soils and site soils to depth of 5 feet assuming lognormal data distribution.
Arsenic	4.30	
Barium	101.0	
Chromium	14.03	
Lead	11.64	
Mercury	0.02*	
Nickel	7.49	
Selenium	1.78	
Thallium	0.2*	
Industrial Workers		
Dermal contact with surface water		
	mg/l	
Barium	0.18	Concentrations are maximum detected concentrations in on-site surface water.
Lead	0.011	

Table 3-6 (Continued)

Populations/Pathways	Exposure Concentrations	Comments
Industrial Workers **Ingestion of groundwater** **Dermal contact with groundwater**		
	mg/l	
Barium	0.30	Concentrations are maximum detected concentrations in site groundwater
Chromium	0.049	
Lead	0.016	
Nickel	0.051	
* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).		

A site-specific volatilization factor (VF) for methylene chloride intake via release from site soils was calculated according to procedures outlined in Section 3.3.1 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of chemical- and site-specific input variables, all default values provided in the guidance were used. The resulting VF for methylene chloride was 5,141 m^3/Kg.

A site-specific value for the particulate emission factor (PEF) used in evaluating inhalation of particulates released from site soils (see equation, Chapter 1) was likewise calculated for LHAAP Site 11 using methodology presented in Section 3.3.2 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of site dimensions, all default variable values presented in this guidance were used in this calculation. The resulting PEF for Site 11 was 2.29E9 m^3/Kg.

Estimated intake rates for all COPC across all exposure pathways are presented in the "Risk Characterization" section of this document.

3.3.4 Identification of Uncertainties. Exposure assessment requires frequent use of professional judgement and estimation of variables used in risk quantification. This frequently leads to varying degrees of uncertainty in final risk estimates. Areas of uncertainty and estimated magnitude of effects of these areas in exposure assessment for this evaluation are listed in Table 3-7. These factors should always be considered in evaluating conclusions of this baseline risk assessment for LHAAP Site 11.

An area of uncertainty in exposure assessment for this study concerns judgmental selection of soils and ditch sampling locations. This may result in bias in development of exposure concentrations for on-site human receptors. While the potential exists for over- or underestimation of exposure with use of these data, it is likely that overestimation may result due to collection of data in areas with highest potential for contamination. In addition, issues regarding use of soils data from depths greater than those frequently used for evaluating surface exposure add uncertainty to these estimates as discussed in previous sections of this report.

As indicated in Table 3-7, many areas of uncertainty associated with this baseline risk assessment may result in overestimation of risk. This results from the practice of employing conservative assumptions throughout exposure assessment and evaluation.

3.4 TOXICITY ASSESSMENT. Toxicological information for all chemicals of potential concern at LHAAP Site 11 has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this chapter. Section 2.4 should be consulted for toxicity information related to chemicals of concern at this site.

Table 3-7. Summary of Areas of Uncertainty for Exposure Assessment
Site 11, Longhorn Army Ammunition Plant

Assumption	Effect on Exposure*		
	Potential Magnitude for Over-estimation of Exposure	Potential Magnitude for Under-estimation of Exposure	Potential Magnitude for Over- or Under-estimation of Exposure
Environmental Sampling and Analysis			
Sampling locations judgmental (nonrandom). May result in bias in data.			Moderate
Sufficient sample numbers may not have been collected.		Moderate	
Passage of time since soils data collection may have resulted in release of VOCs and currently lower concentrations.	Low		
Low levels of methylene chloride in site soils may be result of lab contamination.	Low		
Use of soil depths greater than 0-6 inches in surface exposure estimation.			Low
Exposure Parameter Estimation			
Standard assumptions used in intake calculations may not reflect actual exposure.			Moderate
Use of maximum detected values for pathways involving exposure to groundwater and surface water.	Moderate		
Installation of water supply well may not occur under future industrial land use scenario.	Low		
Exposure parameters for current recreational land use may overestimate exposure.	Low		
Use of total body surface area for dermal exposure estimates.	Moderate		

* As a general guideline, assumptions marked as "low" may affect estimates of exposures by less than one order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between one and two orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than two orders of magnitude.

3.5 RISK CHARACTERIZATION

3.5.1 General. The final step of the risk assessment process is risk characterization. This process involves integration of exposure assessment results and toxicity information in quantitative estimates of risk to human health. Quantified potential risk estimates are segregated by values representing both carcinogenic and noncarcinogenic health effects and are initially developed for individual chemicals via specific exposure routes. Next, risk estimates for individual chemicals (carcinogenic and noncarcinogenic) for each exposure pathway are summed to obtain total pathway risk. Finally, total pathway risks are summed, when appropriately representing total receptor exposure, to yield an estimate of total site risk for carcinogenic as well as noncarcinogenic effects. For this risk assessment, these procedures were used for risk characterization for both RME and CTE under current and future land use scenarios.

For carcinogens, "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk)" (USEPA 1989). Risk estimates are obtained by multiplying daily intakes by published or calculated SFs. A maximum target risk range of 10^{-4} to 10^{-6} serves as a Superfund site remediation goal under the National Contingency Plan (USEPA 1989) and has generally been acknowledged as representative of acceptable risk.

Noncarcinogenic risk estimates are obtained by calculation of a non-cancer hazard quotient. The hazard quotient assumes that there is a level of exposure below which it is unlikely that even sensitive subpopulations will experience adverse health effects. If exposure exceeds this threshold, there may be concern for potential non-cancer health effects (USEPA 1989).

Chemical-specific hazard quotients are calculated by dividing intakes by published RfDs for oral routes of exposure, or by use of calculated inhalation RfDs (explained in Chapter 1) for inhalation exposure. As in carcinogenic risk estimation, hazard quotients are then summed for individual pathways and a hazard index (HI) obtained. Finally, estimates of total non-cancer site risks are obtained by summing total HIs for all appropriate exposure pathways. Final HIs (as well

as chemical or pathway-specific indices) in excess of unity (1.0) are an indication of possible 019942
non-cancer health concerns associated with the site.

Quantification of risks are frequently hindered by a lack of toxicological data for some site chemicals. This lack of data should always be considered in site-related decisions based on quantified risk estimation results.

Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios at LHAAP Site 11 are all presented below.

3.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at Site 11 are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

3.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates derived for current recreational land use are presented in Tables 3-8 and 3-9 for RME and CTE, respectively. Evaluation of these estimates reveal that non-cancer risks are dominated by exposure to metals (principally chromium) via dermal contact with site soils (RME pathway HI = 2E-2) and, to a lesser degree, incidental ingestion of site soils. It should be noted that all detected concentrations of arsenic and chromium in site soils and ditch sediments were well within the facility background range for these metals (Tables 3-2 and 3-3). Low levels of methylene chloride contributed little to overall non-cancer risks for all exposure pathways. Total exposure HIs of 3E-2 and 1E-2 (RME and CTE, respectively) are extremely low, well below unity, and are not indicative of non-cancer health concerns for current land use at LHAAP Site 11.

Table 3-8. Hazard Index Estimates, Site 11, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Methylene Chloride	1.29E-8	6E-2	Liver toxicity	IRIS	100	1	2.2E-7		
Arsenic	4.90E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.6E-3		
Barium	1.30E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.7E-3		
Chromium	1.68E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Lead	1.35E-6	Inappropriate For Evaluation							
Mercury	2.35E-9	1.5E-5	Hand tremor	EPA Reg. VI			1.6E-4		
Nickel	8.10E-7	1.0E-3	Decreased weight	IRIS	300	1	8.1E-4		
Selenium	2.49E-7	2.5E-4	Selenosis	IRIS	3	1	9.9E-4		
Thallium	2.35E-8	Withdrawn							
								2E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Methylene Chloride	2.57E-9	6E-2	Liver toxicity	IRIS	100	1	4.3E-8		
Arsenic	9.76E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.3E-3		
Barium	2.58E-5	7E-2	Incr. blood press.	IRIS	3	1	3.7E-4		
Chromium	3.34E-6	5E-3[3]	None given	IRIS	500	1	6.7E-4		
Lead	2.68E-6	Inappropriate For Evaluation							
Mercury	4.68E-9	3E-4	Hand tremor	EPA Reg. VI			1.6E-5		
Nickel	1.61E-6	2E-2	Decreased weight	IRIS	300	1	8.1E-5		
Selenium	4.96E-7	5E-3	Selenosis	IRIS	3	1	9.9E-5		
Thallium	4.68E-8	Withdrawn							
								5E-3	

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Table 3-8 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	8.55E-11								
Barium	2.26E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			5.5E-5		
Chromium	2.93E-10								
Lead	2.35E-10	Inappropriate For Evaluation							
Mercury	4.10E-13	8.58E-5	Hand tremor	EPA Reg. VI			4.8E-9		
Nickel	1.41E-10								
Selenium	4.35E-11								
Thallium	4.10E-12								
								6E-5	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Methylene Chloride	1.00E-7	2.45E-1	Liver toxicity	EPA Reg. VI			4.1E-7		
								4E-7	
Exposure Pathway: Dermal Contact With Surface Water (Wading)[1]									
Barium	2.89E-6	3.5E-3	Incr. blood press.	IRIS	3	1	8.3E-4		
Lead	7.08E-10	Inappropriate For Evaluation							
								8E-4	
									3E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

Table 3-9. Hazard Index Estimates, Site 11, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Methylene Chloride	2.58E-9	6E-2	Liver toxicity	IRIS	100	1	4.3E-8		
Arsenic	9.80E-8	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.3E-4		
Barium	2.58E-7	3.5E-3	Incr. blood press.	IRIS	3	1	7.4E-5		
Chromium	3.35E-7	2.5E-4[3]	None given	IRIS	500	1	1.3E-3		
Lead	2.68E-7	Inappropriate For Evaluation							
Mercury	4.70E-10	1.5E-5	Hand tremor	EPA Reg. VI			3.1E-5		
Nickel	1.62E-7	1.0E-3	Decreased weight	IRIS	300	1	1.6E-4		
Selenium	4.98E-8	2.5E-4	Selenosis	IRIS	3	1	2.0E-4		
Thallium	4.70E-9	Withdrawn							
								2E-3	
Exposure Pathway: Incidental Ingestion of Soil									
Methylene Chloride	2.57E-9	6E-2	Liver toxicity	IRIS	100	1	4.3E-8		
Arsenic	9.76E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.3E-3		
Barium	2.58E-5	7E-2	Incr. blood press.	IRIS	3	1	3.7E-4		
Chromium	3.34E-6	5E-3	None given	IRIS	500	1	6.7E-4		
Lead	2.68E-6	Inappropriate For Evaluation							
Mercury	4.68E-9	3E-4	Hand tremor	EPA Reg. VI			1.6E-5		
Nickel	1.61E-6	2E-2	Decreased weight	IRIS	300	1	8.1E-5		
Selenium	4.96E-7	5E-3	Selenosis	IRIS	3	1	9.9E-5		
Thallium	4.68E-8	Withdrawn							
								5E-3	

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Table 3-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	8.55E-11								
Barium	2.26E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			5.5E-5		
Chromium	2.93E-10								
Lead	2.35E-10	Inappropriate For Evaluation							
Mercury	4.10E-13	8.58E-5	Hand tremor	EPA Reg. VI			4.8E-9		
Nickel	1.41E-10								
Selenium	4.35E-11								
Thallium	4.10E-12								
								6E-5	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Methylene Chloride	1.00E-7	2.45E-1	Liver toxicity	EPA Reg. VI			4.1E-7		
								4E-7	
Exposure Pathway: Dermal Contact With Surface Water (Wading)[1]									
Barium	2.89E-6	3.5E-3	Incr. blood press.	IRIS	3	1	8.3E-4		
Lead	7.08E-10	Inappropriate For Evaluation							
								8E-4	
									1E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 3-10. Cancer Risk Estimates, Site 11, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	1.85E-9	7.5E-3	B2	Liver	IRIS	1.4E-11		
Arsenic	7.00E-8	1.5E+0	A	Various	IRIS	1.1E-7		
Lead	1.92E-7	Inappropriate For Evaluation						
							1E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	3.69E-10	7.5E-3	B2	Liver	IRIS	2.8E-12		
Arsenic	1.40E-7	1.5E+0	A	Various	IRIS	2.1E-7		
Lead	3.83E-7	Inappropriate For Evaluation						
							2E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	1.22E-11	5E+1	A	Lung	HEAST	6.1E-10		
Lead	3.35E-11							
Chromium	4.18E-11	4.1E+1	A	Lung	HEAST	1.7E-9		
							2E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	1.44E-8	1.65E-3	B2	Neoplasms	IRIS	2.4E-11		
							2E-11	
Exposure Pathway: Dermal Contact With Surface Water[1]								
Lead	1.01E-10	Inappropriate For Evaluation						
								3E-7

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentration (RfC) - see text.

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Table 3-11. Cancer Risk Estimates, Site 11, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	3.68E-10	7.5E-3	B2	Liver	IRIS	2.8E-12		
Arsenic	1.40E-8	1.5E+0	A	Various	IRIS	2.1E-8		
Lead	3.83E-8	Inappropriate For Evaluation						
							2E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	3.69E-10	7.5E-3	B2	Liver	IRIS	2.8E-12		
Arsenic	1.40E-7	1.5E+0	A	Various	IRIS	2.1E-7		
Lead	3.83E-7	Inappropriate For Evaluation						
							2E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	1.22E-11	5E+1	A	Lung	HEAST	6.1E-10		
Lead	3.35E-11							
Chromium	4.18E-11	4.1E+1	A	Lung	HEAST	1.7E-9		
							2E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	1.44E-8	1.65E-3	B2	Neoplasms	IRIS	2.4E-11		
							2E-11	
Exposure Pathway: Dermal Contact With Surface Water[1]								
Lead	1.01E-10	Inappropriate For Evaluation						
								2E-7

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from referenced concentration (RfC) - see text.

3.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 3-10 and 3-11 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to arsenic via incidental ingestion of soils. As noted above, arsenic levels at the site are at background levels established for the facility. In a manner similar to non-cancer risk estimates, methylene chloride contributed little to overall cancer risk for all exposure pathways. Total exposure risk estimates of 3E-7 and 2E-7 (RME and CTE, respectively) are well within the acceptable carcinogenic risk range and do not indicate a concern for cancer-related health effects for current site land use practices. With the exception of lead, toxicity values were available for all evaluated carcinogens, lending increased confidence to these estimates.

3.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of Site 11 would be identical to those presented above. Risk estimates developed for future industrial land use at LHAAP Site 11 are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

3.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use at Site 11 are presented in Tables 3-12 and 3-13 for RME and CTE, respectively. For these estimates, a major contributor to total risk is exposure to chromium via groundwater ingestion (pathway-specific hazard quotients of 9.6E-2 and 6.7E-2 for RME and CTE, respectively). Estimated risks associated with chromium ingestion in groundwater may be overestimated due to the use of maximum detected values and the use of an RfD for Chromium VI (most conservative species). It should also be emphasized that all chromium concentrations reported for groundwater at Site 11 were well within the LHAAP background range (Table 3-1). Total site exposure HIs of 3E-1 and 2E-1 are also well below the critical value of 1.0 and do not indicate concern for non-cancer health effects associated with future industrial use of LHAAP Site 11. Additionally, lead concentrations are well below the 2,000 ppm screening level for non-residential adult exposure (see Section 2.4.2).

Table 3-12. Hazard Index Estimates, Site 11, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Methylene Chloride	6.00E-8	6E-2	Liver toxicity	IRIS	100	1	1.0E-6		
Arsenic	2.15E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.0E-2		
Barium	5.05E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Chromium	7.03E-6	2.5E-4[3]	None given	IRIS	500	1	3.0E-2		
Lead	5.83E-6	Inappropriate For Evaluation							
Mercury	1.00E-8	1.5E-5	Hand tremor	EPA Reg. VI			6.7E-4		
Nickel	3.75E-6	1.0E-3	Decreased weight	IRIS	300	1	3.8E-3		
Selenium	8.90E-7	2.5E-4	Selenosis	IRIS	3	1	3.6E-3		
Thallium	1.00E-7	Withdrawn							
								6E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Methylene Chloride	5.87E-9	6E-2	Liver toxicity	IRIS	100	1	9.8E-8		
Arsenic	2.10E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	7.0E-3		
Barium	4.94E-5	7E-2	Incr. blood press.	IRIS	3	1	7.1E-4		
Chromium	6.86E-6	5E-3	None given	IRIS	500	1	1.4E-3		
Lead	5.69E-6	Inappropriate For Evaluation							
Mercury	9.78E-9	3E-4	Hand tremor	EPA Reg. VI			3.3E-5		
Nickel	3.66E-6	2E-2	Decreased weight	IRIS	300	1	1.8E-4		
Selenium	8.70E-7	5E-3	Selenosis	IRIS	3	1	1.7E-4		
Thallium	9.78E-8	Withdrawn							
								9E-3	

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Table 3-12 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	3.67E-10								
Barium	8.63E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			2.1E-4		
Chromium	1.20E-9								
Lead	9.94E-10	Inappropriate For Evaluation							
Mercury	1.71E-12	8.58E-5	Hand tremor	EPA Reg. VI			2.0E-8		
Nickel	6.40E-10								
Selenium	1.52E-10								
Thallium	1.71E-11								
								2E-4	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Methylene Chloride	4.57E-7	2.45E-1	Liver toxicity	EPA Reg. VI			1.9E-6		
								2E-6	
Exposure Pathway: Dermal Contact With Surface Water (Wading)[1]									
Barium	1.00E-05	3.5E-3	Incr. blood press.	IRIS	3	1	2.9E-3		
Lead	2.95E-09	Inappropriate For Evaluation							
								3E-3	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Barium	1.22E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.5E-3		
Chromium	1.92E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Lead	2.50E-9	Inappropriate For Evaluation							
Nickel	1.98E-6	1.0E-3	Decreased weight	IRIS	300	1	2.0E-3		
								2E-2	

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Table 3-12 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Barium	2.93E-3	7E-2	Incr. blood press.	IRIS	3	1	4.2E-2		
Chromium	4.79E-4	5E-3	None given	IRIS	500	1	9.6E-2		
Lead	1.56E-4	Inappropriate For Evaluation							
Nickel	4.99E-4	2E-2	Decreased weight	IRIS	300	1	2.5E-2		
								2E-1	
									3E-1

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentration (RfC) - see text.

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Table 3-13. Hazard Index Estimates, Site 11, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Methylene Chloride	1.17E-8	6E-2	Liver toxicity	IRIS	100	1	2.0E-7		
Arsenic	4.20E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.4E-3		
Barium	9.88E-6	3.5E-3	Incr. blood press.	IRIS	3	1	2.8E-3		
Chromium	1.37E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Lead	1.14E-6	Inappropriate For Evaluation							
Mercury	1.96E-9	1.5E-5	Hand tremor	EPA Reg. VI			1.3E-4		
Nickel	7.33E-7	1.0E-3	Decreased weight	IRIS	300	1	7.3E-4		
Selenium	1.74E-7	2.5E-4	Selenosis	IRIS	3	1	7.0E-4		
Thallium	1.96E-8	Withdrawn							
								2E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Methylene Chloride	5.87E-9	6E-2	Liver toxicity	IRIS	100	1	9.8E-8		
Arsenic	2.10E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	7.0E-3		
Barium	4.94E-5	7E-2	Incr. blood press.	IRIS	3	1	7.1E-4		
Chromium	6.86E-6	5E-3	None given	IRIS	500	1	1.4E-3		
Lead	5.69E-6	Inappropriate For Evaluation							
Mercury	9.78E-9	3E-4	Hand tremor	EPA Reg. VI			3.3E-5		
Nickel	3.66E-6	2E-2	Decreased weight	IRIS	300	1	1.8E-4		
Selenium	8.70E-7	5E-3	Selenosis	IRIS	3	1	1.7E-4		
Thallium	9.78E-8	Withdrawn							
								9E-3	

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Table 3-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	3.67E-10								
Barium	8.63E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			2.1E-4		
Chromium	1.20E-9								
Lead	9.94E-10	Inappropriate For Evaluation							
Mercury	1.71E-12	8.58E-5	Hand tremor	EPA Reg. VI			2.0E-8		
Nickel	6.40E-10								
Selenium	1.52E-10								
Thallium	1.71E-11								
								2E-4	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]									
Methylene Chloride	4.57E-7	2.45E-1	Liver toxicity	EPA Reg. VI			1.9E-6		
								2E-6	
Exposure Pathway: Dermal Contact With Surface Water (Wading)[1]									
Barium	1.00E-05	3.5E-3	Incr. blood press.	IRIS	3	1	2.9E-3		
Lead	2.95E-09	Inappropriate For Evaluation							
								3E-3	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Barium	1.22E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.5E-3		
Chromium	1.92E-6	2.5E-4	None given	IRIS	500	1	1.0E-2		
Lead	2.50E-9	Inappropriate For Evaluation							
Nickel	1.98E-6	1.0E-3	Decreased weight	IRIS	300	1	2.0E-3		
								2E-2	

019954

Table 3-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Barium	2.06E-3	7E-2	Incr. blood press.	IRIS	3	1	2.9E-2		
Chromium	3.36E-4	5E-3	None given	IRIS	500	1	6.7E-2		
Lead	1.10E-4	Inappropriate For Evaluation							
Nickel	3.49E-4	2E-2	Decreased weight	IRIS	300	1	1.8E-2		
								1E-1	
									2E-1

[1] Intakes are dermally absorbed doses.

[2] RfD (inhalation) calculated from reference concentration (RfC) - see text.

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Table 3-14. Cancer Risk Estimates, Site 11, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	2.10E-8	7.5E-3	B2	Liver	IRIS	1.6E-10		
Arsenic	7.53E-7	1.5E+0	A	Various	IRIS	1.1E-6		
Lead	2.04E-6	Inappropriate For Evaluation						
							1E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	2.09E-9	7.5E-3	B2	Liver	IRIS	1.6E-11		
Arsenic	7.48E-7	1.5E+0	A	Various	IRIS	1.1E-6		
Lead	2.03E-6	Inappropriate For Evaluation						
							1E-6	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	1.31E-10	5E+1	A	Lung	HEAST	5.7E-9		
Lead	3.55E-10	Inappropriate For Evaluation						
Chromium	4.28E-10	4.1E+1	A	Lung	HEAST	1.8E-8		
							2E-8	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	1.63E-7	1.65E-3	B2	Neoplasms	IRIS	2.7E-10		
							3E-10	

019956

Table 3-14 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Surface Water[1]								
Lead	1.05E-9	Inappropriate For Evaluation						
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Lead	8.93E-10	Inappropriate For Evaluation						
Exposure Pathway: Ingestion of Groundwater								
Lead	5.58E-5	Inappropriate For Evaluation						
								2E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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Table 3-15. Cancer Risk Estimates, Site 11, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Methylene Chloride	1.51E-9	7.5E-3	B2	Liver	IRIS	1.1E-11		
Arsenic	5.40E-8	1.5E+0	A	Various	IRIS	8.1E-8		
Lead	1.46E-7	Inappropriate For Evaluation						
							8E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Methylene Chloride	7.55E-10	7.5E-3	B2	Liver	IRIS	5.7E-12		
Arsenic	2.70E-7	1.5E+0	A	Various	IRIS	4.1E-7		
Lead	7.32E-7	Inappropriate For Evaluation						
							4E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	4.73E-11	5E+1	A	Lung	HEAST	2.4E-9		
Lead	1.28E-10	Inappropriate For Evaluation						
Chromium	1.54E-10	4.1E+1	A	Lung	HEAST	6.3E-9		
							9E-9	
Exposure Pathway: Inhalation of Organic Vapors From Site Soils[2]								
Methylene Chloride	5.87E-8	1.65E-3	B2	Neoplasms	IRIS	9.7E-11		
							1E-10	

Table 3-15 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Surface Water[1]								
Lead	3.79E-10	Inappropriate For Evaluation						
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Lead	3.22E-10	Inappropriate For Evaluation						
Exposure Pathway: Ingestion of Groundwater								
Lead	1.02E-2	Inappropriate For Evaluation						
								5E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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3.5.3.2 Cancer Risk Estimates. Cancer risk estimates for future industrial land use are presented in Tables 3-14 and 3-15 for RME and CTE, respectively. Similar to estimates for recreational land use, cancer risk for this scenario is driven by exposure to arsenic via dermal exposure and soil ingestion. Total exposure risk estimates of 2E-6 (RME) and 5E-7 (CTE) are well within the acceptable cancer risk range, are primarily the result of exposure to background levels of naturally-occurring metals, and do not indicate a concern for cancer-related health effects associated with future industrial use of LHAAP Site 11. The inability to evaluate carcinogenic risks associated with lead exposure for all pathways should be considered an uncertainty associated with these estimates.

3.5.4 Uncertainties Associated with Risk Estimates. Estimates of potential risk to human health from contaminant release at LHAAP Site 11 have been presented in this baseline risk assessment. Associated with these estimates are uncertainties in the risk calculation process as well as underlying assumptions forming the basis for risk evaluation. While some of these uncertainties have been briefly discussed throughout this report, further discussion of several areas of uncertainty is provided below.

As exposure via dermal contact contributed to site risk, uncertainties for this pathway were evaluated. An area of uncertainty for this pathway is the use of absorption-corrected oral toxicity data in risk characterization. While this is the approach currently recommended by the USEPA, it is recognized that use of these values may lead to considerable uncertainty and potential over- or underestimation of risk associated with dermal contact (USEPA 1992c). In addition, use of assumed skin surface areas available for contact for site receptors (Table 1-1) may overestimate or underestimate exposure under both land use scenarios and may contribute to uncertainty for estimates involving dermal contact.

Some degree of uncertainty also exists for non-cancer risk estimates for pathways involving inhalation. Reference concentrations (and resulting calculated inhalation RfDs) are lacking for many chemicals evaluated for this pathway. This area of uncertainty should be considered in 019961 interpretation of non-cancer risk estimates.

3.5.5 Risk Summarization. Total risk estimates derived as a result of this baseline risk assessment are summarized in Table 3-16. While these values are provided and discussed above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline risk assessment do not indicate any unacceptable risk to human health associated with continued current or future land uses at Site 11 in the absence of site remediation.

Table 3-16. Summary of Baseline Risk Estimates
Site 11, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	3E-2	Chromium*/Dermal Contact (Soil)
CTE	1E-2	Arsenic*/Soil Ingestion
Cancer Risk		
RME	3E-7	Arsenic*/Soil Ingestion
CTE	2E-7	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	3E-1	Chromium*/Groundwater Ingestion
CTE	2E-1	Chromium*/Groundwater Ingestion
Cancer Risk		
RME	2E-6	Arsenic*/Dermal Contact and Soil Ingestion
CTE	5E-7	Arsenic*/Soil Ingestion
* All concentrations within LHAAP facility background range.		

3.6 SUMMARY

3.6.1 General. A baseline risk assessment was prepared to support site management decisions for LHAAP Site 11 (Suspected TNT Burial Site). The assessment represents an estimate of potential human health impacts resulting from contaminant release from the site in the absence of remediation. Methodology used in the assessment was that prescribed by the USEPA.

3.6.2 Chemicals of Potential Concern. Chemicals of potential concern in site soils and ditch sediments included several metals at levels approximating background concentrations and methylene chloride which was detected at low levels in two (2) soil borings at the site. While present at background levels, metals were evaluated as chemicals of concern in groundwater as a measure of overall cumulative site risk for future land uses. No detected chemicals at the site were eliminated from evaluation and all were carried through risk quantification procedures.

3.6.3 Exposure Assessment. Completed pathways for potential human exposure to site contaminants were identified for receptors under both current recreational and future industrial land use scenarios. Evaluated pathways for current recreational land use included dermal contact with soils, dermal contact with surface waters, incidental ingestion of soil, inhalation of released volatile compounds (methylene chloride), and inhalation of particulates released from site soils. For future industrial land use, the same pathways were evaluated with the addition of groundwater ingestion and dermal contact with groundwater used as a water supply source. All estimation techniques, assumptions, methodology, and degrees of uncertainty associated with risk quantification are provided in this report. As a rule, conservative assumptions were used throughout the risk assessment process where possible.

3.6.4 Risk Characterization. Risk characterization for this assessment was conducted by comparison of estimated intakes of chemicals with toxicity values for carcinogenic and noncarcinogenic health effects. Ranges of cancer and non-cancer risk estimates for both current and future land use scenarios at LHAAP Site 11 are summarized in Table 3-16 of this document.

Total risk estimates for both cancer and non-cancer health effects for all land use scenarios were within acceptable risk ranges.

3.6.5 Conclusion. The objective of this baseline risk assessment was to provide an estimate of risk to human health at LHAAP Site 11 in the absence of remediation. Based on the assumptions, approaches, methods, and uncertainties presented in this document, unacceptable risk to human receptors was not identified. As such, this assessment fails to support the need for site remediation for protection of human health.

HUMAN HEALTH EVALUATION ADDENDUM

3A.1 INTRODUCTION AND OBJECTIVES

3A.1.1 Introduction. Following a review of Phase 1 and 2 data collected at LHAAP Site 11 and human health risk characterization based on these results (as previously presented in this chapter), limited additional surface soil sampling was conducted at the site. This sampling was conducted to facilitate comparison of chemical constituent concentrations in site surface soils with results of previous investigations and to further evaluate the potential for presence of explosive compounds (particularly TNT) in surface soils. Site-specific objectives for these additional evaluations, sampling results, and associated conclusions are presented in this addendum. Addendum results are in no way meant to replace or supersede original human health risk evaluations, but are provided as supplemental information for comprehensive risk evaluation at the site.

3A.1.2 Addendum Objectives. Additional surface soil sampling at Site 11 was conducted at two locations. Objectives of this additional sampling were to compare chemical concentrations in 0- to 6-inch soil depths and those from slightly deeper soil samples employed in original risk evaluations and to further evaluate the potential for presence of explosive compounds at the site. Objectives did not include reevaluation of original risk estimates unless warranted by findings of addendum surface soil sampling.

3A.2 ADDENDUM SAMPLING ACTIVITIES AND RESULTS

3A.2.1 Addendum Sampling Activities. Details of surface soil sampling activities for the Site 11 addendum are described in Section 4 of the Group 1 RI Report (Volume I). In summary, one surface sample was collected in the vicinity of former soil boring 0801 (Figure 3-1). A second surface soil sample was collected approximately 50 feet east of this location. Sampling locations were previously shown in Figure 4-1 of the Group 1 RI report (Volume I). Both surface soil samples were analyzed for high explosives (EPA Method 8330) and the 23 Target Analyte List (TAL) metals.

3A.2.2 Addendum Sampling Results. Chemicals detected in addendum surface soil samples are summarized in Table 3A-1. Most notable was a lack of detection of explosive compounds in either sample (sample quantitation limit of 0.500 mg/Kg for TNT). Metals concentrations in addendum surface soils were generally lower than those from original risk evaluations (Table 3-2) and within facility background levels (Table 3A-1).

3A.2.3 Comparison with Previous Results. As an objective of this addendum was to compare chemical constituents in addendum surface (0- 6-inch depth) soils and those used in original Site 11 risk evaluations, values for the two sampling efforts were compared (Table 3A-2). All metals concentrations in addendum surface soil samples were well within ranges used in previous risk evaluations and also within background ranges established for the facility (Table 3A-2). While analyses for some TAL metals were not conducted during Phase I and II sampling, concentrations of these metals in addendum samples were also within the background range for LHAAP (Table 3A-2). In terms of potential risk calculations using addendum data,

Table 3A-1. Chemicals Detected in Soils[1]
Site 11 Addendum, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[2]
Metals (mg/Kg)				
Arsenic	2/2	--	1.15-1.58	2.3-29.7
Barium	2/2	--	41.5-57.7	35.1-287
Chromium	2/2	--	5.67-6.07	3.2-22.8
Nickel	2/2	--	5.43-5.74	1.5-6.3
Lead	2/2	--	6-8	2.6-17.4
Aluminum	2/2	--	3,400-4,360	1,270-20,700
Calcium	2/2	--	242-403	124-1,090
Cobalt	1/2	<2.92-3.15	2.92	1.5-19.1
Copper	2/2	--	4.02-4.35	0.88-6.7
Iron	2/2	--	4,510-12,000	2,450-31,000
Potassium	2/2	--	372-382	133-481
Magnesium	2/2	--	199-211	68.4-474
Manganese	2/2	--	199-234	10.9-2,330
Vanadium	2/2	--	11.2-32.9	NA[3]
Zinc	2/2	--	13.6-16.6	3.4-16.2

[1] 0 to 6-inch depth.
[2] Range of detected concentrations in surface (0-0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant, (USACE 1995b).
[3] Not available.

Table 3A-2. Comparison of Soil Sample Results, Site 11 Addendum, Longhorn Army Ammunition Plant

Chemical	Range of Detected Concentrations (Phase I and II)[1]	Range of Detected Concentrations (Addendum)[2]	Background Range[3]
Arsenic	2-9.7	1.15-1.58	2.3-29.7
Barium	25.8-167	41.5-57.7	35.1-287
Chromium	1.4-18.5	5.67-6.07	3.2-22.8
Lead	4.0-22	6-8	2.6-17.4
Mercury	0.01-0.02	ND[4] (<0.134)	<0.5
Nickel	1.5-9.6	5.43-5.74	1.5-6.3
Selenium	0.2-2.3	ND (<0.56)	0.5
Thallium	0.2	ND (<0.6)	14.1
Aluminum	NT[5]	3,400-4,360	1,270-20,700
Calcium	NT	242-403	124-1,090
Cobalt	NT	2.92	1.5-19.1
Copper	NT	4.02-4.35	0.88-6.7
Iron	NT	4,510-12,000	2,450-31,000
Potassium	NT	372-382	133-481
Magnesium	NT	199-211	68.4-474
Manganese	NT	199-234	10.9-2,330
Vanadium	NT	11.2-32.9	NA[6]
Zinc	NT	13.6-16.6	3.4-16.2

1 Table 3-2.
2 Table 3A-1.
3 Range of detected concentrations in surface (0-0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995b).
4 Not detected.
5 Not tested.
6 Not available.

even the use of maximum detected values (Table 3A-1) would result in lower exposure concentrations for all metals relative to those used in original risk estimates (Tables 3-5 and 3-6).

3A.3 ADDENDUM CONCLUSIONS

Objectives of this addendum were to compare chemical concentration data used in original risk calculations with those collected during addendum sampling and to further evaluate the potential presence of explosives compounds at Site 11. Data collected as a result of addendum sampling fail to indicate detectable concentrations of explosives (most notably TNT) in site surface soils. In addition, it appears that chemical concentrations in addendum surface soils and data used in original risk estimation are sufficiently similar to preclude the need for reevaluation of risks to human health. As such, this addendum substantiates conclusions of the original Site 11 assessment and fails to support the need for site remediation for protection of human health.

ECOLOGICAL ASSESSMENT

3.7 INTRODUCTION

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA 1992a). While a "stressor" may be any physical, chemical, or biological entity that induces adverse ecological response, chemicals are stressors most frequently evaluated at hazardous waste sites. This ecological assessment evaluates the potential for such response at LHAAP Site 11 (Suspected TNT Burial Site) and was prepared in accordance with general guidance provided in USEPA (1992a; 1994).

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As described in Chapter 1 of this document, ecological evaluations for all LHAAP Group 1 sites were conducted as initial screening-level assessments. It should be reemphasized that this type of assessment does not attempt to define actual site risks, but is used only to determine whether additional ecological evaluation is warranted at site. Assumptions, methods, and applicability to this type of assessment to LHAAP Site 11 are provided in this evaluation.

Remedial investigation sampling activities and results at Site 11 were presented as part of the human health evaluation earlier in this chapter. As these data also formed the basis for ecological assessment at the site, frequent reference is made to appropriate sections of the human health evaluation to prevent repetitive presentation of information applicable to both assessments.

3.8 PRELIMINARY PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

3.8.1 Environmental Setting. Site 11 is located in the undeveloped central portion of LHAAP immediately north of the intersection of Avenues P and Q (Figure 1-3). A map showing site topography, surface drainage patterns, suspected site limits, and other site features is presented in Figure 3-1. The site consists of a relatively flat area of grass immediately north of the intersection. A heavily-timbered area starts approximately 150 feet north of this intersection and continues to the northern limits of the site (Figure 3-1). Site habitat therefore includes both limited grassy areas which have historically been mowed as well as mixed pine/hardwood forest. Forest species are dominated by such hardwoods as sweetgum, hackberry, several hickory species, and oaks. Also present in the overstory are several species of pine. Ground cover in this area consists partially of vines such as greenbriar, poison ivy, honeysuckle, and ferns. A wide variety of terrestrial animals (Appendix A) common to both grasslands and upland forest habitat would be expected to inhabit portions of the site.

No permanent creeks or streams exist on Site 11, and surface water is limited to that conveyed for short periods following rainfall events in drainage ditches bordering the site. Central Creek is located approximately 0.2 miles north of Site 11 (Figure 1-3).

3.8.2 Endangered and Threatened Species. A complete listing and discussion of endangered and threatened species at LHAAP and surrounding areas are presented in the species inventory report for the facility contained in Appendix A. A review of life histories and habitat requirements for these species indicate that most would not be expected to occur at Site 11. While several of these species might occasionally use or pass through habitat at the site, the area is not known to be of prime importance to or classified as critical habitat for any of these species. None of these species are known to inhabit the site. Accordingly, significant impacts on endangered or threatened species are not anticipated in association with LHAAP Site 11.

3.8.3 Contaminants of Potential Ecological Concern. Complete details of chemical sampling activities at Site 11 are presented in the Group 1 SCSR. These activities and results are summarized in section 3.2 of this chapter. Also detailed in this section of the human health assessment is a discussion of the rationale for selection of COPC. As no detected chemicals at the site were detected in blank samples, all detected constituents were retained for human health evaluation. In a similar manner, an identical set of chemicals was used in evaluating ecological effects.

In summary, the only detected chemicals at the site included methylene chloride which was detected in four (4) samples from site soils (Table 3-2) and several metals. A complete and specific list of chemicals of potential ecological concern is provided in later sections of this evaluation.

3.8.4 Site Conceptual Model for Ecological Exposure. Chemical data collected at Site 11 were evaluated in terms of potential exposure for ecological receptors. This resulted in formulation of a site-specific conceptual model for ecological exposure. Factors considered in this evaluation and the selected exposure model for Site 11 are presented below.

Detected constituents in Site 11 groundwater were limited to four (4) metals (barium, chromium, lead, and nickel), all of which were present at background levels (Table 3-1). These findings and considerable distances to surface water environments (described in section 3.1.2) preclude significant ecological exposure via groundwater recharge to these systems. In addition, low levels and infrequent detection of contaminants in site soils and drainage systems from the site, combined with distances to receiving waters, minimize the potential for contaminant loading to off-site aquatic systems via surface runoff. Finally, on-site surface waters are limited to those conveyed for short periods of time following rainfall events via site drainage swales and ditches. While these waters might provide brief exposure to terrestrial organisms, it is unlikely that wet/dry cycles associated with these ditches would allow establishment of permanent on-site aquatic communities. Accordingly, potential for ecological exposure to both on- and off-site aquatic receptors was considered minimal for this site, and emphasis was focused on exposure to terrestrial organisms.

Owing to the presence of chemicals of potential ecological concern in site soils, potential for exposure to terrestrial organisms to these contaminants via soil ingestion, direct contact, and ingestion of potentially-contaminated prey items was evaluated for this assessment. While direct contact (dermal exposure) was not evaluated for this screening-level assessment, exposure via soil and prey ingestion was considered potentially significant. While a number of exposure scenarios involving different organisms are conceivable, maximum exposure would be expected for organisms with high prey (and associated soil) ingestion rates. As these pathways were considered most significant (and most conservative) for the site, a site conceptual model involving soil and prey ingestion for terrestrial organisms became the focus for the LHAAP Site 11 ecological assessment. For these reasons, feeding guilds represented by the least shrew and woodcock models described in Chapter 1 were evaluated for the site.

3.8.5 Screening-Level Ecotoxicity Values. Following development of a site conceptual exposure model, the next step in the screening-level ecological assessment is development of screening ecotoxicity values for chemicals of concern (USEPA 1994). As these values have not currently been tabulated for ecological effects (in a format similar to IRIS for human health assessments), this generally results in a literature search, evaluation of studies appropriate for exposure pathways and receptor species under consideration, and use of professional judgement in deriving chemical-specific toxicity values. Methodology used in developing screening-level toxicity values all Group 1 sites was previously described in section 3.8.5 of this document (Site 1 ecological evaluation). Identical methodology and values were used in this assessment for Site 11. Resulting toxicity data for both small mammal and avian receptors for this assessment are included among those listed in Appendix C.

3.9 PRELIMINARY EXPOSURE ESTIMATE AND RISK CALCULATION

3.9.1 General. Estimation of exposure and risk calculation comprise the second step in ecological risk screening for a site. Screening-level risk estimates are obtained by comparing maximum, conservative exposure levels with ecotoxicity values for species under evaluation (USEPA 1994). This evaluation conducted for LHAAP Site 11 is presented below.

3.9.2 Preliminary Exposure Estimate. Conservative exposure estimates (doses) for both the least shrew and the American woodcock for Site 11 were obtained using equations and parameter values presented in Chapter 1 of this document. As a further means of providing conservatism to intake estimates, maximum detected concentrations of all COPC in site soils and drainage ditch surface "sediments" were used in dose estimation. As noted in the human health evaluation for this site, drainage ditch soils are dry most of the time. Accordingly, these areas provide a potential source of exposure to ecological receptors in a manner similar to soils. In addition, data obtained for soil samples to a depth of five (5) feet below ground surface were evaluated for use in dose estimation. This depth range was used to account for possible exposure to deep burrowing animals and to provide for ecological risk estimation for potential exposure to subsurface soils should they be exposed through site activities under a future industrial land use scenario (as described in the human health assessment). Accordingly, chemical concentrations used in intake estimations were maximum values from Tables 3-2 and 3-3.

As noted in this chapter, screening dose estimates are based on conservative assumptions and parameter values. Resulting intake estimates for soil and prey ingestion for both model species are presented in the next section of this assessment.

3.9.3 Preliminary Risk Calculation. Although several approaches may be used, the hazard quotient method comparing single effect and exposure values is adequate for screening-level risk estimation (USEPA 1994). This method compares estimated exposure levels to measured or predicted threshold value for effects (RTVs as developed above). This method was used for screening-level assessment for LHAAP Site 11.

Ecological screening risk estimates derived for Site 11 least shrew and woodcock models are presented in Tables 3-17 and 3-18, respectively. Screening hazard quotients developed for each chemical of concern and species were examined for relative contribution to overall screening risk. Hazard quotients approaching or exceeding unity (1.0) received close scrutiny for ecological concern and potential further ecological evaluation.

The overall screening HI for the least shrew model for LHAAP Site 11 was estimated at 1E+1 (Table 3-17). Chemicals contributing the majority of this risk consisted entirely of metals and included chromium, lead, and nickel with screening hazard quotients of 8E+0, 8E-1, and 2E+0, respectively. Accordingly, further consideration was given to interpretation of these results. Contribution of methylene chloride present in Site 11 soils to the overall screening hazard index was negligible with a hazard quotient of 3E-6 for the least shrew model.

The overall screening HI for the American woodcock evaluation was estimated at 9E-1 (Table 3-18), slightly below the critical value of 1.0. While no chemical-specific hazard quotient exceeded unity, the highest estimated value was for nickel (4E-1). Accordingly, further consideration was given to interpretation of results for this metal. Avian toxicity data were not available for methylene chloride and barium, and should be considered an area of uncertainty for these estimates.

In summary, screening-level risk calculations for both the least shrew and woodcock models indicated that further interpretation of results for several metals was warranted for LHAAP Site 11. Collectively, these metals included chromium, lead, and nickel. Screening risk estimates for methylene chloride present in site soils were extremely low and indicative of little or no ecological risk.

3.9.4 Evaluation of Chemicals Driving Screening-Level Risk Estimates. Given the identification of chromium, lead, and nickel as metals driving screening-level risk estimates at LHAAP Site 11, data for these constituents were further evaluated for this assessment. While not initially employed in selection of COPC for the site, this further evaluation first involved comparison with background concentrations for these metals. This evaluation provided a measure of the relative contribution of background metals to overall screening-level risk for the site. As site soils data to a depth of five (5) feet below ground surface were used for this assessment, background values for both surface and subsurface soils (USACE 1995b) were used in this evaluation. A comparison of UCLs of concentrations of these metals in site soils relative to background UCLs is presented in Table 3-19. This approach was used to facilitate comparison of reasonable exposure-relevant metals concentrations for the site with those in background soils.

Table 3-17. Ecological Screening Risk Estimate For Least Shrew Model, Site 11, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Methylene Chloride	6.0E-4	NA	6.0E-4	185	3E-6
Arsenic	2.5E-1	1.2E-1	3.7E-1	3.63	1E-1
Barium	4.3E+0	1.5E+1	1.9E+1	82.9	2E-1
Chromium	5.4E-1	4.0E+0	4.5E+0	0.56	8E+0
Lead	5.7E-1	2.9E+0	3.5E+0	4.6	8E-1
Mercury	5.2E-4	1.8E-3	2.3E-3	31.5	7E-5
Nickel	2.5E-1	4.3E+0	4.6E+0	2.5	2E+0
Selenium	6.0E-2	NA	6.0E-2	0.375	2E-1
Thallium	5.2E-3	NA	5.2E-3	0.6	9E-3
				Screening Hazard Index -	1E+1

* See Appendix C. NA = Not available.

Table 3-18. Ecological Screening Risk Estimate For American Woodcock Model
Site 11, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Methylene Chloride	8.5E-4	NA	8.5E-4	NA	NA
Arsenic	3.6E-1	1.7E-1	5.3E-1	28.9	2E-2
Barium	6.2E+0	2.1E+1	2.7E+1	NA	NA
Chromium	7.7E-1	5.7E+0	6.5E+0	95	7E-2
Lead	8.1E-1	4.2E+0	5.0E+0	26	2E-1
Mercury	7.4E-4	2.6E-3	3.3E-3	0.179	2E-2
Nickel	3.6E-1	6.1E+0	6.4E+0	16.9	4E-1
Selenium	8.5E-2	NA	8.5E-2	0.49	2E-1
Thallium	7.4E-3	NA	7.4E-3	0.768	1E-2
				Screening Hazard Index -	9E-1

* See Appendix C. NA = Not available.

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Table 3-19. Comparison of 95% Upper Confidence Limits (UCL) of Selected Metals in Soils - Site 11 Versus Background. All values are mg/Kg.

Metal	Site 11 95% UCL[1]	Background 95% UCL	
		Surface[2]	Subsurface[3]
Chromium	14.03	16.7	14.5
Lead	11.64	14.6	6.3
Nickel	7.49	4.8	8.6

[1] All soil depths to 5 feet (compare with Table 3-6).
[2] 0- to 6-inch depth (USACE 1995b).
[3] >6-inch depth (USACE 1995b).

A comparison of UCLs for these selected metals at Site 11 reveals that all three metals are present at concentrations approximating background levels (Table 3-19). Accordingly, screening-level ecological risks calculated for the site are driven by constituents present at naturally-occurring concentrations for the facility. These data fail to support evidence of a chemical release of these metals at the site, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, these metals were eliminated from further ecological evaluation at Site 11.

3.9.5 Uncertainties. Evaluation of these screening-level ecological assessment results should include consideration of areas and degrees of uncertainty associated with risk estimates (USEPA 1994). While every attempt was made to minimize areas of uncertainty with the use of conservative assumptions and estimation techniques, numerous areas of uncertainty remain and should be considered in site-related decisions. Areas of uncertainty associated with chemical sampling and analysis at Site 11 were presented in the human health evaluation (Table 3-7) and

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would be equally applicable to use of these data for ecological evaluation. Several additional areas of uncertainty specific to ecological evaluation are described below.

Despite the use of conservative risk estimation techniques, it is always possible that species with unknown, yet elevated sensitivities to certain chemical constituents may exist at a site. It is therefore possible that risk estimation methods may underestimate chemical-related risks for these species.

Another area of uncertainty for ecological assessment always involves use of laboratory dose-response data for estimation of ecological effects on indigenous species at a site. Uncertainties associated with use of these data are further increased by the use of a variety of safety or correction factors used to extrapolate types and degrees of biological response (e.g., chronic versus subchronic effects). Finally, the lack of toxicity data for some chemicals under evaluation often adds to uncertainty for ecological assessment. While conservative assumptions are frequently used in an attempt to mitigate these factors, these areas of uncertainty remain and should be considered in site-related decisions.

3.10 SUMMARY

A screening-level ecological risk assessment was prepared to support site management decisions for LHAAP Site 11 (Suspected TNT Burial Site). The assessment represents a conservative estimate of the potential for ecological concerns at the site and the resulting need (or lack thereof) for further ecological evaluations to support site management decisions. The assessment was conducted based on a site conceptual model of terrestrial organism exposure (using both small mammal and avian species models) to COPC in site soils.

Based on methodology used in this assessment, three (3) metals (chromium, lead, and nickel) were identified as main contributors to screening-level risk estimates. Further evaluation

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of data for Site 11 revealed that these metals exist at concentrations approximating background levels for the facility. Accordingly, these data fail to support evidence of a chemical release of these metals to site soils, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, it is the conclusion of this screening-level assessment that little or no ecological concerns are associated with LHAAP Site 11 and that further ecological evaluations and remediation are unwarranted.

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CHAPTER 4
LHAAP SITE 27
(SOUTH TEST AREA)

HUMAN HEALTH EVALUATION

4.1 SITE DESCRIPTION

4.1.1 Site History. The South Test Area (LHAAP Site 27) was constructed in 1954 and used by the Universal Match Corporation until approximately 1956 for testing photo flash bombs produced at LHAAP. Bombs were tested by exploding them in the air over an elevated, semi-elliptical earthen test pad within the floodplain of Harrison Bayou. Testing was observed and controlled from a building on a hilltop 1,000 feet west-northwest of the test pad. Bombs awaiting testing were reportedly stored in three earth-covered concrete bunkers a few hundred feet west of the observation building. During the late 1950's, illumination devices were demilitarized within pits excavated in the vicinity of the test pad. During the early 1960's, leaking production items (possibly canisters of white phosphorus) were demilitarized in the vicinity of the test pad. Finally, in the early 1980's, approximately 52,000 one-half and one-pound photo flash cartridges were demilitarized in a 500-square-foot area situated about 300 feet east of the observation building and immediately north of the road extending from the observation building to the test pad. The South Test Area has apparently not been used since the early 1980's.

4.1.2 Site Location and Features. LHAAP Site 27 covers an area of approximately 6.6 acres and is in a remote location in the south-central portion of the plant (Figure 1-3). A deteriorated asphalt and gravel road leads to the area from its entrance on Avenue P approximately 1,700 feet northeast of its intersection with Avenue E. A circular, 50-foot-wide fire lane with a 2,000-foot diameter surrounds the site. While much of the site is relatively flat, craters, mounds, and variations in relief are present in certain areas, and dense forest vegetation and undergrowth cover much of the site. The site is located in the floodplain of Harrison Bayou (shown in Figure 1-3) which is somewhat undefined in the area but is approximately 750 feet to the east of Site 27. Surface drainage is to the north and east. A map showing surface topography, suspected site limits, and other site features is presented later in this chapter.

Geology and hydrogeology for Site 27 are described in detail in the Group 1 SCSR. In summary, surficial soils encountered across the site consist of reddish-brown silts to silty sands ranging from approximately 3 to 8 feet thick, with increasing sand content at depth. Groundwater was generally encountered at the site at depths ranging from approximately 7 to 9 feet below ground surface. A hydraulic gradient of 0.004 feet/foot in a north-northeasterly direction was calculated for the site with an estimated horizontal groundwater flow velocity of 0.040 feet/day.

4.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

4.2.1 Remedial Investigation Activities. In 1993, phase 1 remedial investigations were conducted at Site 27 by Ebasco Services, Inc. (Ebasco), while phase 2 sampling activities were conducted by Sverdrup Environmental, Inc. (Sverdrup) in 1994. All information pertaining to sampling methods, boring logs, well diagrams, geotechnical data, survey information, and analytical data are provided in the Group 1 SCSR. While appropriate sections of the SCSR should be consulted for specific details, sampling activities pertinent to this baseline risk assessment are briefly summarized below.

In 1993, Ebasco collected four (4) surface soil samples (0- to 1-foot depth) and twenty (20) soil samples from unsaturated soils in ten (10) soil borings, with uppermost samples generally collected at depths of 0 to 2 and 3 to 5 feet below ground surface. These borings were extended to 7 to 8 feet and groundwater grab samples collected. Sampling activities also included the sampling of two existing monitoring wells (wells 131 and 132), collection of two (2) on-site surface water and ditch sediment samples, and collection of two (2) surface water and sediment samples from Harrison Bayou east of the site. All samples of all environmental media collected during phase 1 efforts were analyzed for VOCs (EPA Method 8240); SVOCs (EPA Method 8270); explosives (EPA Method 8330); total metals, including silver, barium, cadmium, chromium, nickel, and antimony (EPA Method 6010); arsenic (EPA Method 7060); mercury (EPA Method 7470); lead (EPA Method 7421); selenium (EPA Method 7740); and thallium (EPA Method 7841), as well as selected anions.

In 1994, Sverdrup conducted phase 2 sampling at LHAAP Site 27. Sampling efforts included collection of three (3) surface soil samples (0- to 6-inch depth); installation and sampling of four (4) groundwater monitoring wells screened in the shallow, water-bearing transmissive unit beneath the site; and collection of twelve (12) soil samples from borings at installed monitoring well locations. Soil and groundwater samples were analyzed for explosives (EPA Method 8330); total metals, including silver, barium, cadmium, chromium, nickel, and antimony (EPA Method 6010); arsenic (EPA Method 7060); mercury (EPA Method 7470); lead (EPA Method 7421); selenium (EPA Method 7740); and thallium (EPA Method 7841), and selected anions. Surface soil samples were analyzed for chromium and mercury. All on-site phase 1 and phase 2 sampling locations, well locations, and other pertinent site information are shown in Figure 4-1. Harrison Bayou surface water and sediment sampling locations associated with Site 27 (SW/SD-05 and SW/SD-02) are shown in Figure 4-2. Other sampling sites shown in this figure were associated with LHAAP Site XX (next chapter).

4.2.2 <u>Remedial Investigation Results</u>. Complete results of all remedial investigation sampling activities are provided in detail in the Group 1 SCSR. Results forming the basis for this risk assessment are summarized below.

Constituents detected in groundwater at LHAAP Site 27 are summarized in Table 4-1. No volatile or semivolatile organic compounds or explosives were detected in groundwater samples. Detected metals included arsenic, barium, chromium, and nickel. Detected concentrations of arsenic, barium, and chromium were well within background ranges established for LHAAP groundwater (Table 4-1) and below drinking water MCLs of 0.05, 2, and 0.1 mg/l, respectively.

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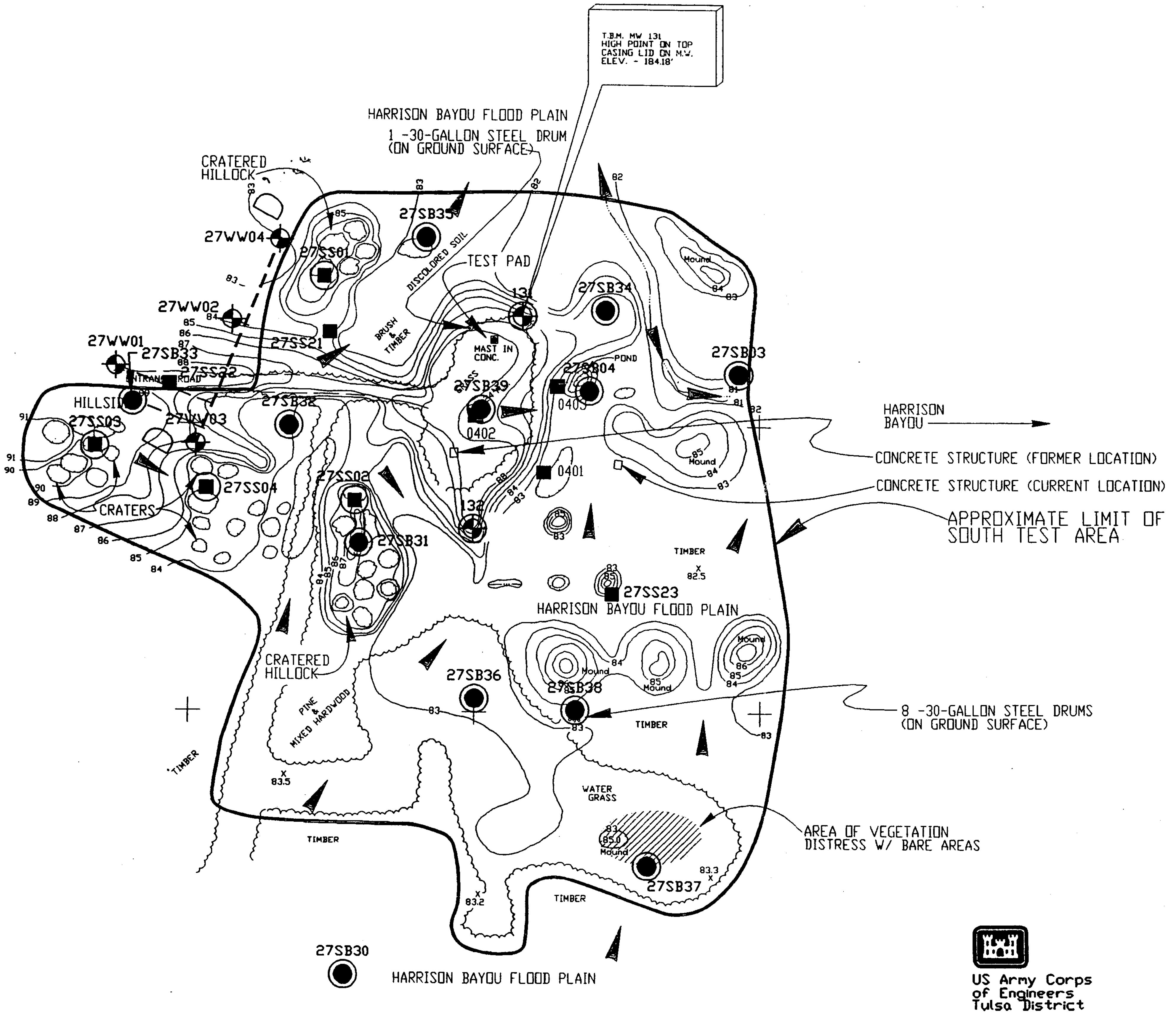

LEGEND

- SHALLOW SOIL SAMPLE (PREVIOUS)
- SURFACE WATER FLOW DIRECTION
- POINT OF COMPLIANCE
- SOIL BORING (PREVIOUS)
- SURFACE SOIL SAMPLE (PREVIOUS)
- MONITORING WELL (EXISTING)
- SURFACE SOIL SAMPLE (PHASE 2)
- MONITORING WELL (PHASE 2)

N

100 0 100 200
SCALE IN FEET

US Army Corps
of Engineers
Tulsa District

NOTE: GROUNDWATER ELEVATION NOV. 89

CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

LHAAP 27
SOUTH TEST AREA
SITE LAYOUT AND
SAMPLE LOCATIONS

Sverdrup Environmental

FIGURE 4-1

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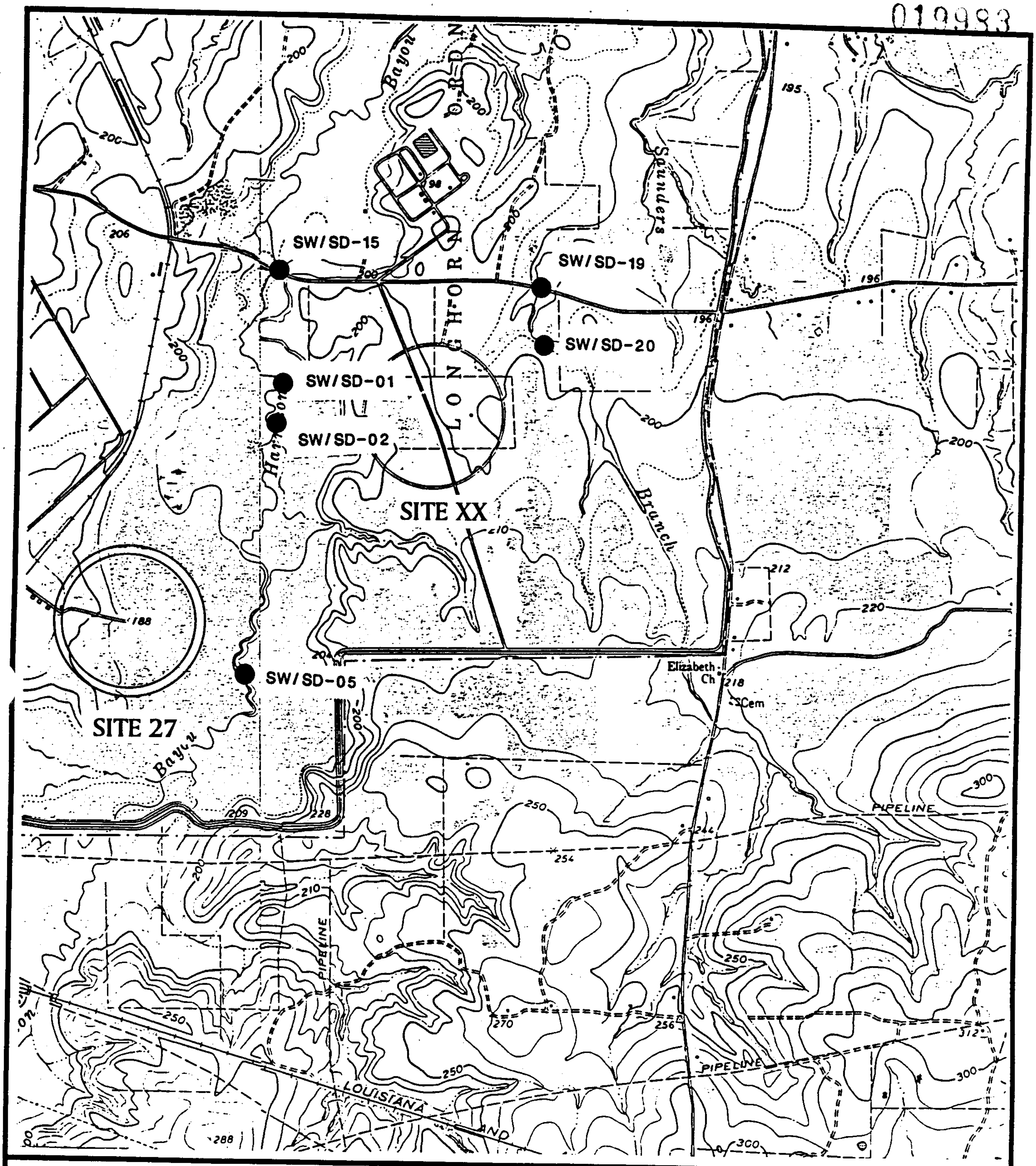

EBASCO	Surface Water/Sediment Sample Location Map
Longhorn Army Ammunition Plant Karnack, Texas	Sites LHXX & LH27
	FIGURE 4-2

Chemical	Frequency of Detection[1]	Sample Quantitation Limits (mg/l)	Range of Detected Concentrations (mg/l)	Background Range[2] (mg/l)
Arsenic	1/8	0.005-0.01	0.006	0.0036-0.022
Barium	7/8	0.02	0.044-0.25	0.02-1.99
Chromium	4/8	0.01-0.05	0.024-0.053	0.01-0.11
Nickel	5/8	0.04-0.05	0.12-0.37	0.02-0.06

Table 4-1. Chemicals Detected in Groundwater
Site 27, Longhorn Army Ammunition Plant

[1] Includes quality control duplicate samples.
[2] Range of detected concentrations from Final Groundwater Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

In contrast, all detected nickel concentrations (0.12 to 0.37 mg/l) exceeded both the upper limits of the LHAAP groundwater background range (0.02 to 0.06 mg/l) and the drinking water MCL for nickel (0.1 mg/l).

Chemicals detected in Site 27 soil samples at depths relevant to risk assessment evaluations are summarized in Table 4-2. This summary includes all soil samples collected at the site to a depth of five (5) feet below ground surface. This depth range is included as it was used in risk estimation for future land use scenarios for the site (explained later in this text). No volatile or semivolatile organic compounds or explosives were detected in site soils. Seven (7) metals were detected in soil samples (Table 4-2). With the exception of a single reported concentration of barium (639 mg/Kg at a depth of 3 to 5 feet in the soil boring for monitoring well 27WW04), all detected metals were within background ranges for the facility. This included nickel despite apparently elevated concentrations of this metal in site groundwater.

Table 4-2. Chemicals Detected in Soils[1]
Site 27, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[2]	Sample Quantitation Limits (mg/Kg)	Range of Detected Concentrations (mg/Kg)	Background Range[3] (mg/Kg)
Arsenic	23/23	--	0.7-2.5J	1.7-36.8
Barium	23/23	--	27.3-639	22-287
Chromium	26/26	--	2.3-22.2	3.2-26.2
Lead	18/23	5.4-9	2-9	1.0-17.4
Mercury	13/26	0.01-0.13	0.02-0.08	0.25
Nickel	21/23	1	1.4-10	1.5-19.1
Selenium	10/23	0.1-1.24	0.1-0.3	0.5

[1] Includes all soil samples to depth of 5 feet.
[2] Includes quality control duplicate samples.
[3] Range of detected concentrations of both surface (0-0.5 feet) and subsurface (>0.5-foot depth) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Chemicals detected in on-site surface waters and ditch sediments are summarized in Table 4-3. No volatile or semivolatile organic compounds or explosives were detected in either medium. Only barium and lead were detected in surface water, and all metals concentrations in ditch sediments were within background ranges for LHAAP surface soils. Despite a limited sample number, these data are not indicative of accumulation or concentration of contaminants in site ditches.

Table 4-3. Chemicals Detected in Surface Water and Ditch Surface Sediments Site 27, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range*
Surface Water (mg/l)				
Barium	2/2	--	0.11-0.29	--
Lead	1/2	0.005	0.015	--
Ditch Sediments (mg/Kg)				
Arsenic	2/2	--	0.9-1.1	2.3-29.7
Barium	2/2	--	43.5-254	35.1-287
Chromium	2/2	--	1.9-5.2	3.2-22.8
Lead	2/2	--	5-8.0	2.6-17.4
Nickel	2/2	--	3.0-3.9	1.5-6.3
Selenium	1/2	0.1	0.2	0.5

* Provided for comparison - range of detected concentrations in surface soils (0-0-5-foot depth) Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Table 4-4. Chemicals Detected in Water and Sediments of Harrison Bayou Longhorn Army Ammunition Plant				
Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range*
Surface Water (mg/l)				
Barium	2/2	--	0.11-0.12	--
Bayou Sediments (mg/Kg)				
Arsenic	2/2	--	0.7-1.1	2.3-29.7
Barium	2/2	--	39.0-91.8	35.1-287
Chromium	2/2	--	2.4-4.6	3.2-22.8
Lead	2/2	--	4.0-9.0	2.6-17.4
Mercury	1/2	0.01	0.03	0.25
Nickel	2/2	--	2.8-6.0	1.5-6.3
* Provided for comparison - range of detected concentrations in surface soils (0-0.5-foot depth) from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).				

Chemicals detected in Harrison Bayou surface water and sediments (0- to 6-inch depth) are summarized in Table 4-4. Due to the relative proximity of Harrison Bayou to Site 27, these data were collected during phase 1 as an indication of potential site impacts on these receiving waters. No volatiles, semivolatiles, or explosives were detected in water or sediment samples. Barium was the only detected metal in surface waters (0.11 to 0.12 mg/l). While not directly comparable, detected metals in Harrison Bayou sediments were evaluated relative to surface soil background levels established for LHAAP as a reasonable approximation of potential impacts (Table 4-4). Detected concentrations were all within background levels. Most notable among bayou sampling results was a lack of elevated concentrations of nickel given Site 27 groundwater sampling results.

A review of data collected during all remedial investigations at LHAAP Site 27 reveals that the site possesses extremely low levels (if any) of soil contamination. Evidence of a chemical release at the site is therefore questionable. However, due to apparently elevated concentrations of nickel in site groundwater, risk evaluations were performed for the site.

4.2.3 Selection of Chemicals of Potential Concern. Environmental data sets described above were evaluated for selection of chemicals for use in quantitative risk assessment. Selection of chemicals was based on rationale described in Chapter 5 of RAGS/HHEM and discussed in Chapter 1 of this document.

Section 5.5 of RAGS/HHEM states that, under certain conditions, chemicals of concern may be eliminated based on comparison with concentrations in blank samples. Concentrations of all detected chemicals at Site 27 were below SQLs in all blank samples (close evaluation was given to nickel concentrations in blank samples associated with groundwater sampling and analysis). Therefore, no chemicals were eliminated as COPC using this protocol. While most detected chemicals were reported at levels approximating background concentrations, all detected chemicals were retained as COPC for evaluation of total cumulative risk at the site (as described in Chapter 1). Accordingly, all detected constituents listed in Tables 4-1 through 4-3 were evaluated for quantitative risk analysis.

4.3 EXPOSURE ASSESSMENT

4.3.1 Characterization of Exposure Setting. Site 27 at LHAAP is located in an extremely remote and relatively inaccessible portion of the plant. Work activities associated with LHAAP's mission are far removed from this location, and maintenance is not provided to the area. The site is also a considerable distance from the plant boundary or other areas of activity resulting in minimal potential for exposure for off-site receptors.

4.3.2 Identification of Exposure Pathways. Necessary elements of an exposure pathway include a source of contamination, transport medium, routes of exposure, and human receptors at exposure points (USEPA 1989). Absence of necessary elements results in incomplete exposure pathways indicating that exposure will not occur and no adverse impacts on human health exist for that pathway.

Exposure pathways considered for evaluation for this baseline risk assessment are listed in Table 4-5. Given existing land use and activities at the site, the only conceivable current land use exposure scenario would involve recreational use of the area. While even this is extremely limited at present, occasional deer hunting (during season weekends) is allowed at LHAAP and could result in limited use of the area. It is possible that the area could be frequented by an occasional hiker, bird-watcher, or other recreationist, although current security measures at the plant preclude unlimited public access to these areas. In light of the possibility of limited current recreational activities at the site, an exposure scenario involving recreational use of the area was evaluated for this assessment.

Given the overall lack of contamination at the site and failure to detect site-related contaminants in surface waters and sediments of Harrison Bayou, exposure scenarios involving recreational receptors using Harrison Bayou were not evaluated for this assessment.

Exposure pathways under current recreational land use could include dermal contact with site soils and ditch surface sediments, incidental ingestion of surficial soils, and inhalation of soil particulates. While on-site surface waters are confined to drainage ditches transversing the site which contain water after rainfall events, dermal contact with these waters through wading is conceivable and was evaluated for this assessment. As these waters are of insufficient depth for swimming, the potential for ingestion of surface waters while swimming was considered low and was therefore not evaluated for this site.

Table 4-5. Summary of Exposure Pathways
Site 27, Longhorn Army Ammunition Plant

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
CURRENT LAND USE			
Plant Workers	Various	No	No current work activities at or near site. Pathway is incomplete.
Off-Plant Residents, Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Dermal contact with surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Incidental ingestion of surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of vapors from soils and ditches	No	No volatile compounds detected at site.
On-Site Recreationists	Inhalation of soil and ditch particulates	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Dermal contact with surface waters	Yes	Potential recreational activities at site. Short-term presence of surface waters. Pathway potentially complete.
On-Site Recreationists	Ingestion of surface waters	No	No on-site surface water of depth suitable for swimming. Pathway incomplete.
FUTURE LAND USE			
Off-Plant Residents/ Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Various as listed under current land use	Yes	Potential future recreational activities at site. Pathways potentially complete.

Table 4-5 (Continued)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
FUTURE LAND USE (Continued)			
On-Site Workers	Dermal contact with surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Incidental ingestion of surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of organic vapors from soils and ditches	No	No volatile compounds detected at site.
On-Site Workers	Inhalation of surface and subsurface soil and ditch sediment particulates	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Dermal contact with surface waters	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Ingestion of surface waters	No	No conceivable activities completing this pathway.
On-Site Workers	Ingestion of groundwater from on-site well	Yes	New well installation conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Dermal contact with groundwater	Yes	Showering conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Inhalation of volatiles from groundwater	No	No volatile compounds detected at site.
On-Site Residents	Various	No	Residential land use not conceivabe. Excessed property based on availability and/or remediation to industrial use standards.

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While future land use practices at the site could include continued recreational use, future industrial development of the area is also conceivable (though somewhat in question due to the location of the LHAAP Site 27 within the Harrison Bayou floodplain). This scenario could occur as a result of construction required for mission changes at LHAAP or lease of lands for industrial development. Industrial land use could potentially include excavation of site soils for construction purposes, other earth-moving activities, and maintenance functions resulting in exposure to industrial workers. This land use scenario is less likely for Site 27 than several other Group 1 sites, but was evaluated for the sake of conservatism.

While exposure factors (i.e., exposure duration and frequencies) would most likely differ, exposure pathways under a future industrial land use scenario could include all those described above for recreational use. Despite the existence of a current water supply source at LHAAP and location of the site in a floodplain, it is also plausible that an on-site water supply well could be installed at the site if industrial development were to occur. This would result in the additional exposure pathways of groundwater ingestion and dermal contact with groundwater (primarily through showering) for industrial site workers. As such, these pathways were evaluated under future industrial land use conditions.

Exposed populations for all land use scenarios were assumed to be composed entirely of adults, with no sensitive subpopulations (children, elderly, etc.) present on-site. As current recreational use at the site is primarily limited to deer hunting, small children would most likely not participate in these activities. Likewise, children would not be expected at the site under a future industrial scenario. As such, risk evaluations for this assessment were conducted for adult populations only.

4.3.3 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of

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exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

4.3.3.1 Summary of Exposure Concentrations. Estimates of exposure concentrations for all environmental media and exposure pathways were developed using methodology described in Chapter 1 of this report. A brief explanation of rationale used in estimating exposure concentrations for pathways involving site soils is provided below.

For purposes of exposure estimation, surface soil is generally defined as the shallowest depth that can be practically sampled (i.e., 6 inches or 1 foot) (USEPA 1989; Region VI Supplemental Guidance). Initial soil sampling at LHAAP Site 27 was conducted to investigate the nature and extent of potential contamination from a variety of activities. These activities ranged from aboveground testing of photo flash devices to storage and demilitarization of these devices in depressions or pits with the potential for waste burial or covering by surface materials. Accordingly, initial (phase 1) samples of surficial materials were collected at depths ranging from those commonly used for surface exposure (0 to 1 foot below ground surface) to slightly greater depths (0- to 2-foot depth). Limited samples from depositional areas of drainage ditches were collected at depths of 0 to 6 inches below ground surface as an indication of potential transport of surface contaminants from site soils. Due to a lack of detected contaminants using this approach, extensive sampling of shallower layers was not conducted during phase 2 sampling at the site. As a result, "surface" soils data for this site were obtained from depths ranging from 0 to 6 inches to a maximum of 2 feet below ground surface. Use of these data for surface soil exposure concentration estimates adds some degree of uncertainty to these estimates, but is not considered a significant deficiency given site conditions.

Another consideration involves the use of surface materials collected from site drainage ditches in exposure estimates. These ditches represent shallow drainage pathways transversing the site which generally contain water for a short time only after rainfall events. While the term "sediment" has been applied to samples from these shallow ditches, from an exposure standpoint these surficial materials are similar to site soils in that they provide a source for release of particulates and serve as areas of potential exposure via soil ingestion and dermal contact. As the underlying basis for exposure at a site involves the use of spatially averaged soil concentrations contacted over time (USEPA 1992b), these ditches represent areas of potential soils exposure that should be accounted for in exposure estimates based on spatial averages. For these reasons, data obtained from ditches were combined with those from site soils for all pathways involving direct or indirect (through inhalation) exposure. The fact that these data are based on soil depths of 0 to 6 inches may also partially mitigate uncertainties associated with use of soils samples collected at slightly deeper depths when combined with these data for purposes of surface soil exposure estimation. For Site 27, a limited number of on-site samples (two) and metals concentrations similar to site soils rendered this consideration of little importance to this assessment.

Based on rationale presented above, estimation of exposure concentrations involving site soils under current recreational land use were obtained by applying principles presented in Chapter 1 to soils data from uppermost sampling intervals in site soils and surficial ditch sediments. Estimated exposure concentrations for all site media for the current recreational land use scenario are presented in Table 4-6.

As future industrial land use could potentially involve soil excavation and earth-moving activities, the potential exists for exposure to soils at greater depths under this scenario. Accordingly, soils data from 3- to 5-foot depths were incorporated into these exposure estimates. Concentrations from uppermost sampling intervals and 3- to 5-foot depths (when present) from each soil boring were averaged to obtain a single point estimate over a 5-foot depth for that boring. These values were then combined with ditches data and exposure estimates based on the calculated 95% UCL. Exposure concentration estimates for all pathways under the future industrial land use scenario are presented in Table 4-7.

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Table 4-6. Summary of Exposure Concentrations, **Current Land Use**
Site 27, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Arsenic	1.47	Concentrations are the 95% upper confidence limits or average concentrations in site surface soils and ditches assuming lognormal data distributions.
Barium	122.93	
Chromium	8.41	
Lead	6.58	
Mercury	0.06	
Nickel	5.38	
Selenium	0.30*	
Recreationists **Dermal contact with surface water**		
	mg/l	
Barium	0.29	Concentrations are maximum detected concentrations in on-site surface waters.
Lead	0.015	

* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).

Table 4-7. Summary of Exposure Concentrations, **Future Land Use**
Site 27, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists		
All exposure pathways	Same as listed in Table 4-6 (Current Land Use).	
Industrial Workers		
Incidental ingestion of soil **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Arsenic	1.47	Concentrations are the 95% upper confidence limit on average concentrations of ditch soils and site soils to depth of 5 feet assuming lognormal data distribution.
Barium	139.23	
Chromium	8.61	
Lead	6.51	
Mercury	0.06	
Nickel	5.81	
Selenium	0.30*	
Industrial Workers		
Dermal contact with surface water		
	mg/l	
Barium	0.29	Concentrations are maximum detected concentrations in on-site surface waters.
Lead	0.015	

Table 4-7 (Continued)

Populations/Pathways	Exposure Concentrations	Comments
Industrial Workers **Ingestion of groundwater** **Dermal contact with groundwater**		
	mg/l	
Arsenic	0.006	Concentrations are maximum detected concentrations in site groundwater
Barium	0.25	
Chromium	0.053	
Nickel	0.37	
* 95% UCL exceeds maximum detected concentration. Maximum value used as exposure concentration (USEPA 1989).		

4.3.3.2 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations presented in Chapter 1. All intake equations and variable values used in intake estimates for varying exposure scenarios were presented in this chapter.

A site-specific value for the particulate emission factor (PEF) used in evaluating inhalation of particulates released from site soils (see equation, Chapter 1) was likewise calculated for LHAAP Site 27 using methodology presented in Section 3.3.2 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of site dimensions, all default variable values presented in this guidance were used in this calculation. The resulting PEF for Site 27 was 1.14E9 m^3/Kg.

Estimated intake rates for all COPC across all exposure pathways are presented in the "Risk Characterization" section of this document.

4.3.4 Identification of Uncertainties. Exposure assessment requires frequent use of professional judgement and estimation of variables used in risk quantification. This frequently leads to varying degrees of uncertainty in final risk estimates. Areas of uncertainty and estimated magnitude of effects of these areas in exposure assessment for this evaluation are listed in Table 4-8. These factors should always be considered in evaluating conclusions of this baseline risk assessment for LHAAP Site 27.

An area of uncertainty in exposure assessment for this study concerns judgmental selection of soils and ditch sampling locations. This may result in bias in development of exposure concentrations for on-site human receptors. While the potential exists for over- or underestimation of exposure with use of these data, it is likely that overestimation may result due to collection of data in areas with highest potential for contamination. In addition, issues regarding use of soils data from depths greater than those frequently used for evaluating surface exposure add uncertainty to these estimates as discussed in previous sections of this report.

An additional area of uncertainty for LHAAP Site 27 exposure assessment concerns exposure concentrations for nickel in site groundwater. Since levels of this metal appear to be somewhat elevated in groundwater at the site, it is possible that maximum concentrations were not detected during sampling activities. This could potentially lead to underestimation of site risk and should be considered in risk evaluation.

As indicated in Table 4-8, many areas of uncertainty associated with this baseline risk assessment may result in overestimation of risk. This results from the practice of employing conservative assumptions throughout exposure assessment and evaluation.

Table 4-8. Summary of Areas of Uncertainty for Exposure Assessment
Site 27, Longhorn Army Ammunition Plant

Assumption	Effect on Exposure*		
	Potential Magnitude for Over-estimation of Exposure	Potential Magnitude for Under-estimation of Exposure	Potential Magnitude for Over- or Under-estimation of Exposure
Environmental Sampling and Analysis			
Sampling locations judgmental (nonrandom). May result in bias in data.			Moderate
Sufficient sample numbers may not have been collected.		Low	
Full extent of nickel concentrations in ground-water may be undefined.		Moderate	
Use of soil depths greater than 0-6 inches in surface exposure estimation.			Low
Exposure Parameter Estimation			
Standard assumptions used in intake calculations may not reflect actual exposure.			Moderate
Use of maximum detected values for pathways involving exposure to groundwater and surface water.	Low		
Installation of water supply well may not occur under future industrial land use scenario.	Low		
Industrial development may be unrealistic land use.	Moderate		
Exposure parameters for current recreational land use may overestimate exposure.	Low		
Use of total body surface area for dermal exposure estimates.	Moderate		

* As a general guideline, assumptions marked as "low" may affect estimates of exposures by less than one order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between one and two orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than two orders of magnitude.

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4.4 TOXICITY ASSESSMENT. Toxicological information for all chemicals of potential concern at LHAAP Site 27 has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this chapter. Section 2.4 should be consulted for toxicity information related to chemicals at this site.

4.5 RISK CHARACTERIZATION

4.5.1 General. The final step of the risk assessment process is risk characterization. This process involves integration of exposure assessment results and toxicity information in quantitative estimates of risk to human health. Quantified potential risk estimates are segregated by values representing both carcinogenic and noncarcinogenic health effects and are initially developed for individual chemicals via specific exposure routes. Next, risk estimates for individual chemicals (carcinogenic and noncarcinogenic) for each exposure pathway are summed to obtain total pathway risk. Finally, total pathway risks are summed, when appropriately representing total receptor exposure, to yield an estimate of total site risk for carcinogenic as well as noncarcinogenic effects. For this risk assessment, these procedures were used for risk characterization for both RME and CTE under current and future land use scenarios.

For carcinogens, "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk)" (USEPA 1989). Risk estimates are obtained by multiplying daily intakes by published or calculated SFs. A maximum target risk range of 10^{-4} to 10^{-6} serves as a Superfund site remediation goal under the National Contingency Plan (USEPA 1989) and has generally been acknowledged as representative of acceptable risk.

Noncarcinogenic risk estimates are obtained by calculation of a non-cancer hazard quotient. The hazard quotient assumes that there is a level of exposure below which it is unlikely that even sensitive subpopulations will experience adverse health effects. If the exposure exceeds this threshold, there may be concern for potential non-cancer health effects (USEPA 1989).

Chemical-specific hazard quotients are calculated by dividing intakes by published RfDs for oral routes of exposure, or by use of calculated inhalation RfDs (explained in Chapter 1) for inhalation exposure. As in carcinogenic risk estimation, hazard quotients are then summed for individual pathways and an HI obtained. Finally, estimates of total non-cancer site risks are obtained by summing total HIs for all appropriate exposure pathways. Final HIs (as well as chemical or pathway-specific indices) in excess of unity (1.0) are an indication of possible non-cancer health concerns associated with the site.

Quantification of risks are frequently hindered by a lack of toxicological data for some site chemicals. This lack of data should always be considered in site-related decisions based on quantified risk estimation results.

Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios at LHAAP Site 27 are all presented below.

4.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at Site 27 are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

4.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates derived for current recreational land use are presented in Tables 4-9 and 4-10 for RME and CTE, respectively. Evaluation of these estimates reveal that non-cancer risks are dominated by exposure to metals (principally chromium) via dermal contact with site soils (pathway HI = 1E-2 and 2E-3 for RME and CTE, respectively) and, to a lesser degree, incidental ingestion of site soils. It should be noted that all detected concentrations of chromium in site soils and ditch sediments were within

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the facility background range for this metal (Tables 4-2 and 4-3). Total exposure HIs of 1E-2 and 5E-3 (RME and CTE, respectively) are extremely low, well below unity, and are not indicative of non-cancer health concerns for current land use at LHAAP Site 27.

4.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 4-11 and 4-12 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to arsenic via dermal contact and incidental ingestion of soils. Arsenic levels at the site are at background levels established for the facility (Tables 4-2 and 4-3). Total exposure cancer estimates of 1E-7 and 8E-8 (RME and CTE, respectively) are well within the acceptable carcinogenic risk range and do not indicate a concern for cancer-related health effects for current site land use practices. With the exception of lead, toxicity values were available for all evaluated carcinogens, lending increased confidence to these estimates.

4.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of Site 27 would be identical to those presented above. Risk estimates developed for future industrial land use at LHAAP Site 27 are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

4.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use at Site 27 are presented in Tables 4-13 and 4-14 for RME and CTE, respectively. For these estimates, risk is equally driven by oral exposure to arsenic and nickel via groundwater ingestion (total pathway-specific HIs of 5E-1 and 4E-1 for RME and CTE, respectively). It should be emphasized that risk estimates for arsenic are based on a single detected concentration well within the LHAAP background range (Table 4-1).

Table 4-9. Hazard Index Estimates, Site 27, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.73E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	5.8E-4		
Barium	1.45E-5	3.5E-3	Incr. blood press.	IRIS	3	1	4.1E-3		
Chromium	9.88E-7	2.5E-4[3]	None given	IRIS	500	1	4.0E-3		
Lead	7.73E-7	Inappropriate For Evaluation							
Mercury	7.05E-9	1.5E-5	Hand tremor	EPA Reg. VI			4.7E-4		
Nickel	6.33E-7	1.0E-3	Decreased weight	IRIS	300	1	6.3E-4		
Selenium	3.53E-8	2.5E-4	Selenosis	IRIS	3	1	1.4E-4		
								1E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.44E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.2E-3		
Barium	2.88E-5	7E-2	Incr. blood press.	IRIS	3	1	4.1E-4		
Chromium	1.97E-6	5E-3	None given	IRIS	500	1	3.9E-4		
Lead	1.54E-6	Inappropriate For Evaluation							
Mercury	1.40E-8	3E-4	Hand tremor	EPA Reg. VI			4.7E-5		
Nickel	1.26E-6	2E-2	Decreased weight	IRIS	300	1	6.3E-5		
Selenium	7.02E-8	5E-3	Selenosis	IRIS	3	1	1.4E-5		
								2E-3	

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Table 4-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	6.06E-11								
Barium	5.06E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.2E-4		
Chromium	3.46E-10								
Lead	2.71E-10	Inappropriate For Evaluation							
Mercury	2.47E-12	8.58E-5	Hand tremor	IRIS			2.9E-8		
Nickel	2.22E-10								
Selenium	1.24E-11								
								1E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	4.66E-06	3.5E-3	Incr. blood press.	IRIS	3	1	1.3E-3		
Lead	9.65E-10	Inappropriate For Evaluation							
								1E-3	
									1E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 4-10. Hazard Index Estimates, Site 27, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	3.45E-8	2E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.7E-4		
Barium	2.88E-6	3.5E-3	Incr. blood press.	IRIS	3	1	8.2E-4		
Chromium	1.98E-7	2.5E-4[3]	None given	IRIS	500	1	7.9E-4		
Lead	1.55E-7	Inappropriate For Evaluation							
Mercury	1.41E-9	1.5E-5	Hand tremor	EPA Reg. VI			9.4E-5		
Nickel	1.26E-7	1.0E-3	Decreased weight	IRIS	300	1	1.3E-4		
Selenium	7.05E-9	2.5E-4	Selenosis	IRIS	3	1	2.8E-5		
								2E-3	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.44E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.2E-3		
Barium	2.88E-5	7E-2	Incr. blood press.	IRIS	3	1	4.1E-4		
Chromium	1.97E-6	5E-3[3]	None given	IRIS	500	1	3.9E-4		
Lead	1.54E-6	Inappropriate For Evaluation							
Mercury	1.40E-8	3E-4	Hand tremor	EPA Reg. VI			4.7E-5		
Nickel	1.26E-6	2E-2	Decreased weight	IRIS	300	1	6.3E-5		
Selenium	7.02E-8	5E-3	Selenosis	IRIS	3	1	1.4E-5		
								2E-3	

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Table 4-10 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	6.06E-11								
Barium	5.06E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.2E-4		
Chromium	3.46E-10								
Lead	2.71E-10	Inappropriate For Evaluation							
Mercury	2.47E-12	8.58E-5	Hand tremor	IRIS			2.9E-8		
Nickel	2.22E-10								
Selenium	1.24E-11								
								1E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	4.66E-06	3.5E-3	Incr. blood press.	IRIS	3	1	1.3E-3		
Lead	9.65E-10	Inappropriate For Evaluation							
								1E-3	
									5E-3

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

Table 4-11. Cancer Risk Estimates, Site 27, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	2.47E-8	1.5E+0	A	Various	IRIS	3.7E-8		
Lead	1.11E-7	Inappropriate For Evaluation						
							4E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	4.92E-8	1.5E+0	A	Various	IRIS	7.4E-8		
Lead	2.20E-7	Inappropriate For Evaluation						
							7E-8	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	8.66E-12	5E+1	A	Lung	HEAST	4.3E-10		
Lead	3.88E-11	Inappropriate For Evaluation						
Chromium	4.95E-11	4.1E+1	A	Lung	HEAST	2.0E-9		
							2E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1]								
Lead	1.38E-10	Inappropriate For Evaluation						
								1E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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Table 4-12. Cancer Risk Estimates, Site 27, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	4.93E-9	1.5E+0	A	Various	IRIS	7.4E-9		
Lead	2.21E-8	Inappropriate For Evaluation						
							7E-9	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	4.92E-8	1.5E+0	A	Various	IRIS	7.4E-8		
Lead	2.20E-7	Inappropriate For Evaluation						
							7E-8	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	8.66E-12	5E+1	A	Lung	HEAST	4.3E-10		
Lead	3.88E-11	Inappropriate For Evaluation						
Chromium	4.95E-11	4.1E+1	A	Lung	HEAST	2.0E-9		
							2E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1]								
Lead	1.38E-10	Inappropriate For Evaluation						
								8E-8

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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Table 4-13. Hazard Index Estimates, Site 27, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	7.35E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.4E-3		
Barium	6.95E-5	3.5E-3	Incr. blood press.	IRIS	3	1	2.0E-2		
Chromium	4.30E-6	2.5E-4[3]	None given	IRIS	500	1	2.0E-2		
Lead	3.25E-6	Inappropriate For Evaluation							
Mercury	3.00E-8	1.5E-5	Hand tremor	EPA Reg. VI			2.0E-3		
Nickel	2.90E-6	1.0E-3	Decreased weight	IRIS	300	1	2.9E-3		
Selenium	1.50E-7	2.5E-4	Selenosis	IRIS	3	1	6.0E-4		
								5E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	7.19E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.4E-3		
Barium	6.81E-5	7E-2	Incr. blood press.	IRIS	3	1	9.7E-4		
Chromium	4.21E-6	5E-3[3]	None given	IRIS	500	1	8.4E-4		
Lead	3.18E-6	Inappropriate For Evaluation							
Mercury	2.93E-8	3E-4	Hand tremor	EPA Reg. VI			9.8E-5		
Nickel	2.84E-6	2E-2	Decreased weight	IRIS	300	1	1.4E-4		
Selenium	1.47E-7	5E-3	Selenosis	IRIS	3	1	2.9E-5		
								4E-3	

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Table 4-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	2.53E-10								
Barium	2.39E-8	4.09E-5	Incr. blood press.	EPA Reg. VI			5.8E-4		
Chromium	1.48E-9								
Lead	1.12E-9	Inappropriate For Evaluation							
Mercury	1.03E-11	8.58E-5	Hand tremor	IRIS			1.2E-7		
Nickel	9.99E-10								
Selenium	5.16E-11								
								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	2.00E-05	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Lead	4.02E-09	Inappropriate For Evaluation							
								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Arsenic	2.35E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	7.8E-4		
Barium	9.78E-6	3.5E-3	Incr. blood press.	IRIS	3	1	2.8E-3		
Chromium	2.06E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Nickel	1.45E-5	1.0E-3	Decreased weight	IRIS	300	1	1.0E-2		
								2E-2	

Table 4-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Arsenic	5.87E-5	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.0E-1		
Barium	2.45E-3	7E-2	None given	IRIS	3	1	3.5E-2		
Chromium	5.18E-4	5E-3[3]	None given	IRIS	500	1	1.0E-1		
Nickel	3.62E-3	2E-2	Decreased weight	IRIS	300	1	1.8E-1		
								5E-1	
									6E-1

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 4-14. Hazard Index Estimates, Site 27, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.44E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	4.8E-4		
Barium	1.36E-5	3.5E-3	Incr. blood press.	IRIS	3	1	3.9E-3		
Chromium	8.43E-7	2.5E-4[3]	None given	IRIS	500	1	3.4E-3		
Lead	6.38E-7	Inappropriate For Evaluation							
Mercury	5.88E-9	1.5E-5	Hand tremor	EPA Reg. VI			3.9E-4		
Nickel	5.68E-7	1.0E-3	Decreased weight	IRIS	300	1	5.7E-4		
Selenium	2.93E-8	2.5E-4	Selenosis	IRIS	3	1	1.2E-4		
								1E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	7.19E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.4E-3		
Barium	6.81E-5	7E-2	Incr. blood press.	IRIS	3	1	9.7E-4		
Chromium	4.21E-6	5E-3[3]	None given	IRIS	500	1	8.4E-4		
Lead	3.18E-6	Inappropriate For Evaluation							
Mercury	2.93E-8	3E-4	Hand tremor	EPA Reg. VI			9.8E-5		
Nickel	2.84E-6	2E-2	Decreased weight	IRIS	300	1	1.4E-4		
Selenium	1.47E-7	5E-3	Selenosis	IRIS	3	1	2.9E-5		
								4E-3	

Table 4-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	2.53E-10								
Barium	2.39E-8	4.09E-5	Incr. blood press.	EPA Reg. VI			5.8E-4		
Chromium	1.48E-9								
Lead	1.12E-9	Inappropriate For Evaluation							
Mercury	1.03E-11	8.58E-5	Hand tremor	IRIS			1.2E-7		
Nickel	9.99E-10								
Selenium	5.16E-11								
								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	2.00E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Lead	4.02E-9	Inappropriate For Evaluation							
								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Arsenic	2.35E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	7.8E-4		
Barium	9.78E-8	3.5E-3	Incr. blood press.	IRIS	3	1	2.8E-5		
Chromium	2.06E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Nickel	1.45E-5	1.0E-3	Decreased weight	IRIS	300	1	1.0E-2		
								2E-2	

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Table 4-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Arsenic	4.11E-5	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.4E-1		
Barium	1.71E-3	7E-2	Incr. blood press.	IRIS	3	1	2.4E-2		
Chromium	3.63E-4	5E-3[3]	None given	IRIS	500	1	7.3E-2		
Nickel	2.53E-3	2E-2	Decreased weight	IRIS	300	1	1.3E-1		
								4E-1	
									4E-1

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Given apparently elevated concentrations of nickel in Site 27 groundwater, close evaluation was given to estimated non-cancer risks associated with exposure to this metal via groundwater ingestion. Estimated ranges for nickel-specific hazard quotients for this route of exposure were 1.8E-1 and 1.3E-1 for RME and CTE, respectively, and are not cause for concern for non-cancer health effects. Contribution of this chemical to overall non-cancer risk is approximately 30%. Total site exposure HIs of 6E-1 (RME) and 4E-1 (CTE) are also below the critical value of 1.0 and do not indicate concern for non-cancer health effects associated with future industrial use of LHAAP Site 27. Additionally, lead concentrations in soils were well-below the 2,000 ppm screening level for non-residential adult exposure (see Section 2.4.2)

4.5.3.2 Cancer Risk Estimates. Cancer risk estimates for future industrial land use are presented in Tables 4-15 and 4-16 for RME and CTE, respectively. Cancer risk for this scenario is driven by exposure to arsenic via groundwater ingestion with chemical-specific risk estimates of 3E-5 (RME) and 8E-6 (CTE). As previously noted, the single detected arsenic concentration in site groundwater is within the background range for LHAAP (Table 4-1). Total exposure risk estimates of 3E-5 (RME) and 8E-6 (CTE) are well within the acceptable cancer risk range, are primarily the result of exposure to background levels of naturally-occurring metals, and do not indicate a concern for cancer-related health effects associated with future industrial use of LHAAP Site 27. The inability to evaluate carcinogenic risks associated with lead exposure for all pathways should be considered an uncertainty associated with these estimates.

4.5.4 Uncertainties Associated with Risk Estimates. Estimates of potential risk to human health from contaminant release at LHAAP Site 27 have been presented in this baseline risk assessment. Associated with these estimates are uncertainties in the risk calculation process as well as underlying assumptions forming the basis for risk evaluation. While some of these uncertainties have been briefly discussed throughout this report, further discussion of several areas of uncertainty is provided below.

Table 4-15. Cancer Risk Estimates, Site 27, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	2.58E-7	1.5E+0	A	Various	IRIS	3.9E-7		
Lead	1.14E-6	Inappropriate For Evaluation						
							4E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	2.56E-7	1.5E+0	A	Various	IRIS	3.8E-7		
Lead	1.13E-6	Inappropriate For Evaluation						
							4E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	9.01E-11	5E+1	A	Lung	HEAST	4.5E-9		
Lead	3.99E-10	Inappropriate For Evaluation						
Chromium	5.28E-10	4.1E+1	A	Lung	HEAST	2.2E-8		
							3E-8	
Exposure Pathway: Dermal Contact With Surface Waters[1]								
Lead	1.44E-9	Inappropriate For Evaluation						

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Table 4-15 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Arsenic	8.37E-8	1.5E+0	A	Various	IRIS	1.3E-7	1E-7	
Exposure Pathway: Ingestion of Groundwater								
Arsenic	2.09E-5	1.5E+0	A	Various	IRIS	3.1E-5	3E-5	
								3E-5

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

Table 4-16. Cancer Risk Estimates, Site 27, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	1.85E-8	1.5E+0	A	Various	IRIS	2.8E-8		
Lead	8.18E-8	Inappropriate For Evaluation						
							3E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	9.25E-8	1.5E+0	A	Various	IRIS	1.4E-7		
Lead	4.09E-7	Inappropriate For Evaluation						
							1E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	3.25E-11	5E+1	A	Lung	HEAST	1.6E-9		
Lead	1.44E-10	Inappropriate For Evaluation						
Chromium	1.90E-10	4.1E+1	A	Lung	HEAST	7.8E-9		
							9E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1]								
Lead	5.17E-10	Inappropriate For Evaluation						

Table 4-16 (Continued)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Arsenic	3.01E-8	1.5E+0	A	Various	IRIS	4.5E-8	5E-8	
Exposure Pathway: Ingestion of Groundwater								
Arsenic	5.28E-6	1.5E+0	A	Various	IRIS	7.9E-6	8E-6	
								8E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks - see text.

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As exposure via dermal contact contributed to site risk, uncertainties for this pathway were evaluated. An area of uncertainty for this pathway is the use of absorption-corrected oral toxicity data in risk characterization. While this is the approach currently recommended by the USEPA, it is recognized that use of these values may lead to considerable uncertainty and potential over- or underestimation of risk associated with dermal contact (USEPA 1992c). In addition, use of assumed skin surface areas available for contact for site receptors (Table 1-1) may overestimate or underestimate exposure under both land use scenarios and may contribute to uncertainty for estimates involving dermal contact.

Some degree of uncertainty also exists for non-cancer risk estimates for pathways involving inhalation. Reference concentrations (and resulting calculated inhalation RfDs) are lacking for many chemicals evaluated for this pathway. This area of uncertainty should be considered in interpretation of non-cancer risk estimates.

4.5.5 Risk Summarization. Total risk estimates derived as a result of this baseline risk assessment are summarized in Table 4-17. While these values are provided and discussed above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline risk assessment do not indicate any unacceptable risk to human health associated with continued current or future land uses at Site 27 in the absence of site remediation.

4.6 SUMMARY

4.6.1 General. A baseline risk assessment was prepared to support site management decisions for LHAAP Site 27 (Signal Test Area). The assessment represents an estimate of potential human health impacts resulting from contaminant release from the site in the absence of remediation. Methodology used in the assessment was that prescribed by the USEPA.

Table 4-17. Summary of Baseline Risk Estimates
Site 27, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	1E-2	Chromium* and Barium/Dermal Contact with Soil
CTE	5E-3	Arsenic*/Soil Ingestion
Cancer Risk		
RME	1E-7	Arsenic*/Soil Ingestion
CTE	8E-8	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	6E-1	Arsenic* and Nickel/Groundwater Ingestion
CTE	4E-1	Arsenic* and Nickel/Groundwater Ingestion
Cancer Risk		
RME	3E-5	Arsenic*/Groundwater Ingestion
CTE	8E-6	Arsenic*/Groundwater Ingestion

* All concentrations within LHAAP facility background range.

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4.6.2 Chemicals of Potential Concern. Chemicals of potential concern in site soils and ditch sediments included several metals at levels approximating background concentrations. Chemicals of concern in groundwater included several metals within background ranges and below drinking water MCLs. Most notable among groundwater COPC was nickel which exceeded its MCL and background levels in all detected samples. No detected chemicals at the site were eliminated from evaluation and all were carried through risk quantification procedures.

4.6.3 Exposure Assessment. Completed pathways for potential human exposure to site contaminants were identified for receptors under both current recreational and future industrial land use scenarios. Evaluated pathways for current recreational land use included dermal contact with soils, dermal contact with surface waters, incidental ingestion of soil, and inhalation of particulates released from site soils. For future industrial land use, the same pathways were evaluated with the addition of groundwater ingestion and dermal contact with groundwater used as a water supply source. All estimation techniques, assumptions, methodology, and degrees of uncertainty associated with risk quantification are provided in this report. As a rule, conservative assumptions were used throughout the risk assessment process where possible.

4.6.4 Risk Characterization. Risk characterization for this assessment was conducted by comparison of estimated intakes of chemicals with toxicity values for carcinogenic and noncarcinogenic health effects. Ranges of cancer and non-cancer risk estimates for both current and future land use scenarios at LHAAP Site 27 are summarized in Table 4-17 of this document. Total risk estimates for both cancer and non-cancer health effects for all land use scenarios were within acceptable risk ranges.

4.6.5 Conclusion. The objective of this baseline risk assessment was to provide an estimate of risk to human health at LHAAP Site 27 in the absence of remediation. Based on the assumptions, approaches, methods, and uncertainties presented in this document, unacceptable risk to human receptors was not identified. As such, this assessment fails to support the need for site remediation for protection of human health.

4A.1 INTRODUCTION AND OBJECTIVES

4A.1.1 Introduction. Following a review of Phase 1 and 2 data collected at LHAAP Site 27 and human health risk characterization based on these results (as previously presented in this chapter), limited additional surface soil sampling was conducted at the site. This sampling was initiated to support additional human health risk characterization for a limited area at Site 27 identified during review of original risk assessment results. Site-specific objectives for these additional evaluations, sampling results, and resulting additional risk estimates are presented in this addendum. Addendum results are in no way meant to replace or supersede original human health risk evaluations, but are provided as supplemental information for comprehensive risk evaluation at the site.

4A.1.2 Addendum Objectives. Additional surface soil sampling at Site 27 was conducted at an elevated "pad" area formerly used in testing photo flash bombs at the site (see Section 4.1). This area covers approximately one-third of an acre and is located in the vicinity of former soil boring 0402 (Figure 4-1). As this area represents a potential location for accumulation of surface contaminants, the primary objective of this addendum was to evaluate this limited area as a potential "hot spot" for human exposure as recommended in RAGS/HHEM (USEPA 1989) and to further evaluate the potential for explosives (in particular TNT) in surface soils at this location. Additional objectives included verification of the similarity between chemical concentrations in 0- to 6-inch soil depths and slightly deeper depths employed in original risk evaluations and expansion of the number of metals used in risk characterization.

4A.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

4A.2.1 Addendum Sampling Activities. Details of surface soil sampling activities for Site 27 addendum risk evaluation are described in Section 7 of the Group 1 RI Report. In summary, nine (9) surface soil (0- to 6-inch depth) samples were collected from the elevated pad area using an approximate 50-foot grid spacing. Sampling locations are provided in Figure 7-1 of the Group 1 RI report.

All samples were analyzed for high explosives (including 2,4,6-TNT) using EPA Method 8330. In addition, four (4) randomly-selected samples were analyzed for the 23 Target Analyte List (TAL) metals.

4A.2.2 Addendum Sampling Results. Chemicals detected in addendum surface soil samples are summarized in Table 4A-1. Most notably, no explosive compounds were detected in any soil sample from the area (sample quantitation limit was 0.500 mg/Kg for TNT). A number of metals were detected at concentrations which sometimes exceeded background levels (Table 4A-1). Concentrations of arsenic, chromium, lead, and selenium were slightly higher than those observed in Phase 1 and 2 sampling, while barium and nickel levels were lower than previous results (compare to Table 4-2).

4A.2.3 Selection of Chemicals of Potential Concern. Chemicals which are essential human nutrients and present at low concentrations are generally eliminated as chemicals of potential concern (COPC) in human health risk evaluation. These constituents commonly include iron, magnesium, calcium, and potassium (Supplemental Region VI Risk Assessment Guidance, May 1995). Accordingly, these chemicals were eliminated as COPC for this evaluation. With these exceptions, chemicals selected for use as COPC in quantitative human health risk assessment for pathways involving exposure to surface soils for this addendum included all detected chemicals listed in Table 4A-1. No other chemicals were eliminated and all were carried through to risk characterization.

Table 4A-1. Chemicals Detected in Soils[1]
Site 27 Addendum, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[2]
Metals (mg/Kg)				
Arsenic	4/4	--	6.08-13.1	2.3-29.7
Barium	4/4	--	69.5-123	35.1-287
Cadmium	4/4	--	8.54-21.0	1.25
Chromium	4/4	--	15.2-36.3	3.2-22.8
Nickel	1/4	2.06-2.11	2.41	1.5-6.3
Lead	4/4	--	11-18	2.6-17.4
Selenium	3/4	0.52	0.66-0.83	0.5
Aluminum	4/4	--	4,350-10,300	1,270-20,700
Beryllium	1/4	0.62-0.66	1.16	NA[3]
Calcium	4/4	--	392-809	124-1,090
Copper	4/4	--	5.65-18.7	0.88-6.7
Iron	4/4	--	21,800-70,000	2,450-31,000
Potassium	4/4	--	150-513	133-481
Magnesium	4/4	--	187-635	68.4-474
Manganese	4/4	--	135-223	10.9-2,330
Strontium	1/4	12.5-15.4	16.8	2.3-13.3
Vanadium	4/4	--	25.6-72.4	NA[3]
Zinc	4/4	--	19.6-41.3	3.4-16.2

[1] 0 to 6-inch depth.
[2] Range of detected concentrations in surface (0-0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant, (USACE 1995b).
[3] Not available.

4A.3 EXPOSURE ASSESSMENT

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4A.3.1 Identification of Exposure Pathways. Land use assumptions and exposure pathways identical to those employed in original risk estimates (Table 4-5) were retained for this addendum. Accordingly, risk evaluations for current recreational, future recreational, and future industrial land uses and all associated exposure pathways were evaluated. These pathways are described in Section 4.3 of the original human health evaluation for Site 27.

In accordance with the objective of providing "hot spot" risk estimates for the site, quantified risks for all pathways involving dermal contact and incidental ingestion of soils were generated using only surface soil data collected for this addendum (Table 4A-1). Conceivably, chemical intakes for receptors exclusively using this limited area would also be influenced by exposure to other environmental media (groundwater, surface waters, and fugitive dust generated across the entire site). Therefore, as a measure of total cumulative risk to human receptors, risk estimates for these pathways, as established in the original assessment, were included in risk characterization for this addendum.

4A.3.2 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

4A.3.3. Summary of Exposure Concentrations. Exposure concentrations for all pathways involving dermal contact with soils and soil ingestion were estimated using maximum detected values (Table 4A-1). While 95% upper confidence limits (UCLs) on average concentrations in soils assuming lognormal data distributions are generally used in estimating exposure concentrations (and was used in original evaluation), small soil sample sizes for this addendum made use of this method somewhat impractical. Sample size for metals analyses was small (n=4) and maximum values were used in an attempt to maintain consistency with addendum evaluations for other Group 1 sites (see discussion for Site 1 addendum). It should be emphasized that this approach adds conservatism to risk estimates as UCLs for many COPC would be less than maximum detected values. Typically, maximum values are used only when UCLs exceed these concentrations (USEPA 1992b).

Concentrations of COPC in soils to a depth of 5 feet were used in original exposure calculations for future industrial land use receptors (see Section 4.3.3.2). As subsurface soils were not collected for use in this addendum, data from surface soils were used in estimating exposure under industrial as well as recreational land use for this addendum. Accordingly, exposure concentrations for all pathways involving dermal contact with soils and soil ingestion for this addendum are presented in Table 4A-2.

4A.3.4 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations and variable values employed in original risk evaluations and presented in Chapter 1. Identical values and equations were retained for use in estimating intakes for this addendum. Estimated intake rates for all COPC are presented in the "Risk Characterization" section of this addendum.

4A.3.5 Identification of Uncertainties. Most areas of uncertainty and estimated magnitude of effects in exposure assessment identified in original risk evaluations for Site 27 (Section 4.3.4, Table 4-8) would be applicable to this addendum. An additional area of uncertainty would include the use of maximum detected concentrations for pathways involving soil exposure and would most likely result in overestimation of exposure for some chemicals. Similarly, uncertainty results from the use of only surface soils data for pathways involving soil exposure under future industrial land use scenarios. This may over- or underestimate exposure depending upon the extent of future excavation activities at this limited site area and relative differences between COPC concentrations in surface and subsurface soils.

Table 4A-2. Summary of Soil Exposure Concentrations,
Current and Future Land Use,
Site 27 Addendum, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
<u>Recreationists/Industrial Workers</u> **Incidental ingestion of soil** **Dermal contact with soil**		
	mg/Kg	
Arsenic	13.1	Concentrations are maximum detected concentrations in addendum surface soil samples. Upper confidence limits not used due to small sample sizes.
Barium	123	
Cadmium	21.0	
Chromium	36.3	
Nickel	2.41	
Lead	18	
Selenium	0.83	
Aluminum	10,300	
Beryllium	1.16	
Copper	18.7	
Manganese	223	
Strontium	16.8	
Vanadium	72.4	
Zinc	41.3	

4A.4 TOXICITY ASSESSMENT

Toxicological information for COPC at LHAAP Site 27 has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this addendum. Section 2.4 should be consulted for toxicity information related to chemicals of concern.

4A.5 RISK CHARACTERIZATION

4A.5.1 General. Risk characterization for this addendum was performed in an identical manner to that for the original assessment. Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios are all presented below.

4A.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at the limited area of Site 27 are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

4A.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for current recreational land use are presented in Tables 4A-3 and 4A-4 for RME and CTE, respectively. Evaluation of these estimates reveal that RME non-cancer risks are dominated by exposure to metals (principally chromium and vanadium) via dermal contact with soils (pathway HI = 7E-2). Exposure to metals (principally cadmium) via soil ingestion dominated CTE non-cancer risks (pathway HI =2E-2). Total exposure HIs of 9E-2 and 3E-2 (RME and CTE, respectively) are somewhat higher than original risk estimates for the site as a whole (Table 4-17), but are still extremely low. Both estimates are well below unity and are therefore not indicative of non-cancer health concerns for current land use at this limited area of Site 27.

Table 4A-3. Hazard Index Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.53E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	1.44E-5	3.5E-3	Blood pressure	IRIS	3	1	4.1E-3		
Cadmium	2.46E-6	3E-4	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	4.25E-6	2.5E-4[2]	None given	IRIS	500	1	2.0E-2		
Nickel	2.82E-7	1.0E-3	Decreased weight	IRIS	300	1	2.8E-4		
Lead	2.11E-6	Inappropriate for Evaluation							
Selenium	9.71E-8	2.5E-4	Selenosis	IRIS	3	1	3.9E-4		
Aluminum	1.21E-3								
Beryllium	1.36E-7	2.5E-4		IRIS	100	1	5.4E-4		
Copper	2.19E-6								
Manganese	2.61E-5	1E-2	CNS Effects	IRIS	1	1	2.6E-3		
Strontium	1.97E-6	3E-2	Rachitic Bone	IRIS	300	1	6.6E-5		
Vanadium	8.47E-6	3.5E-4		HEAST			2.0E-2		
Zinc	4.83E-6	1.5E-2	ESOD Decrease	IRIS	3	1	3.2E-4		
								7E-2	

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Table 4A-3 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.07E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	2.88E-5	7E-2	Blood pressure	IRIS	3	1	4.1E-4		
Cadmium	4.91E-6	1E-3	Proteinuria	IRIS	10	1	4.9E-3		
Chromium	8.49E-6	5E-3[2]	None given	IRIS	500	1	1.7E-3		
Nickel	5.64E-7	2E-2	Decreased weight	IRIS	300	1	2.8E-5		
Lead	4.21E-6	Inappropriate For Evaluation							
Selenium	1.94E-7	5E-3	Selenosis	IRIS	3	1	3.9E-5		
Aluminum	2.41E-3								
Beryllium	2.71E-7	5E-3		IRIS	100	1	5.4E-5		
Copper	4.38E-6								
Manganese	5.22E-5	1.4E-1	CNS Effects	IRIS	1	1	3.7E-4		
Strontium	3.93E-6	6E-1	Rachitic Bone	IRIS	300	1	6.6E-6		
Vanadium	1.69E-5	7E-3		HEAST			2.4E-3		
Zinc	9.66E-6	3E-1	ESOD Decrease	IRIS	3	1	3.2E-5		
								2E-2	
Exposure Pathway: Inhalation of Particulates[3]								1E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1,3]								1E-3	
									9E-2

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Chromium VI.
[3] See Table 4-9.

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Table 4A-4. Hazard Index Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	3.08E-7	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-3		
Barium	2.89E-6	3.5E-3	Blood pressure	IRIS	3	1	8.3E-4		
Cadmium	4.94E-7	3E-4	Proteinuria	IRIS	10	1	1.7E-3		
Chromium	8.53E-7	2.5E-4[2]	None given	IRIS	500	1	3.4E-3		
Nickel	5.66E-8	1.0E-3	Decreased weight	IRIS	300	1	5.7E-5		
Lead	4.23E-7	Inappropriate for Evaluation							
Selenium	1.95E-8	2.5E-4	Selenosis	IRIS	3	1	7.8E-5		
Aluminum	2.42E-4								
Beryllium	2.73E-8	2.5E-4		IRIS	100	1	1.1E-4		
Copper	4.39E-7								
Manganese	5.24E-6	1E-2	CNS Effects	IRIS	1	1	5.2E-4		
Strontium	3.95E-7	3E-2	Rachitic Bone	IRIS	300	1	1.3E-5		
Vanadium	1.70E-6	3.5E-4		HEAST			4.9E-3		
Zinc	9.71E-7	1.5E-2	ESOD Decrease	IRIS	3	1	6.5E-5	1E-2	

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Table 4A-4 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.07E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	2.88E-5	7E-2	Blood pressure	IRIS	3	1	4.1E-4		
Cadmium	4.91E-6	1E-3	Proteinuria	IRIS	10	1	4.9E-3		
Chromium	8.49E-6	5E-3[2]	None given	IRIS	500	1	1.7E-3		
Nickel	5.64E-7	2E-2	Decreased weight	IRIS	300	1	2.8E-5		
Lead	4.21E-6	Inappropriate For Evaluation							
Selenium	1.94E-7	5E-3	Selenosis	IRIS	3	1	3.9E-5		
Aluminum	2.41E-3								
Beryllium	2.71E-7	5E-3		IRIS	100	1	5.4E-5		
Copper	4.38E-6								
Manganese	5.22E-5	1.4E-1	CNS Effects	IRIS	1	1	3.7E-4		
Strontium	3.93E-6	6E-1	Rachitic Bone	IRIS	300	1	6.6E-6		
Vanadium	1.69E-5	7E-3		HEAST			2.4E-3		
Zinc	9.66E-6	3E-1	ESOD Decrease	IRIS	3	1	3.2E-5		
								2E-2	
Exposure Pathway: Inhalation of Particulates[3]								1E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1,3]								1E-3	
									3E-2

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Chromium VI.
[3] See Table 4-10.

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4A.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 4A-5 and 4A-6 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to beryllium via dermal contact (chemical-specific risk = 1.7E-6) for RME exposure and exposure to arsenic via soil ingestion (chemical-specific risk = 6.6E-7) for CTE exposure. It should be noted that all arsenic concentrations detected in addendum sampling were within surface soil background concentrations established for the facility (Table 4A-1). Total exposure risk estimates of 3E-6 and 1E-6 (RME and CTE, respectively) are higher than original estimates for the site as a whole (Table 4-17) but are well within the acceptable carcinogenic risk range. These results indicate no concern for cancer-related health effects for current land use practices at this limited site area. With the exception of lead, toxicity values were available for all evaluated carcinogens, lending increased confidence to these estimates.

4A.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of the limited area at Site 27 (represented by addendum sampling) would be identical to those presented above. Risk estimates developed for future industrial land use for this area are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

4A.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use are presented in Tables 4A-7 and 4A-8 for RME and CTE, respectively. Similar to original estimates, a major contributor to total risk is exposure to arsenic and nickel via groundwater ingestion (pathway-specific hazard indices of 5E-1 and 4E-1 for RME and CTE, respectively). Findings related to this exposure pathway and conservative assumptions used in risk estimation are explained in Section 4.5.3.1. Total site exposure HIs of 9E-1 and 5E-1 (RME and CTE) are somewhat higher than those for original risk estimates for the site as a whole but are still below the critical value of 1.0, and therefore do not indicate concern for non-cancer health effects associated with future industrial land use of this limited area of Site 27. Conservative assumptions used in risk estimation (principally use of maximum detected values for soils and groundwater) should also be considered in evaluation of these findings.

Table 4A-5. Cancer Risk Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	2.20E-7	1.5E+0	A	Various	IRIS	3.3E-7		
Lead	3.02E-7	Inappropriate For Evaluation						
Beryllium	1.95E-8	8.6E+1	B2	Various	IRIS	1.7E-6		
							2E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	4.39E-7	1.5E+0	A	Various	IRIS	6.6E-7		
Lead	6.03E-7	Inappropriate For Evaluation						
Beryllium	3.89E-8	4.3E+0	B2	Various	IRIS	1.7E-7		
							8E-7	
Exposure Pathway: Inhalation of Particulates[2]							2E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1]							-----	
								3E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 4-11.

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Table 4A-6. Cancer Risk Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	4.39E-8	1.5E+0	A	Various	IRIS	6.6E-8		
Lead	6.03E-8	Inappropriate For Evaluation						
Beryllium	3.89E-9	8.6E+1	B2	Various	IRIS	3.4E-7		
							4E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	4.39E-7	1.5E+0	A	Various	IRIS	6.6E-7		
Lead	6.03E-7	Inappropriate For Evaluation						
Beryllium	3.89E-8	4.3E+0	B2	Various	IRIS	1.7E-7		
							8E-7	
Exposure Pathway: Inhalation of Particulates[2]							2E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1]							-----	
								1E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 4-12.

Table 4A-7. Hazard Index Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	6.55E-6	3E-4	Hyperpigmentation	IRIS	3	1	2.0E-2		
Barium	6.15E-5	3.5E-3	Blood pressure	IRIS	3	1	2.0E-2		
Cadmium	1.05E-5	3E-4	Proteinuria	IRIS	10	1	4.0E-2		
Chromium	1.82E-5	2.5E-4[2]	None given	IRIS	500	1	7.0E-2		
Nickel	1.21E-6	1.0E-3	Decreased weight	IRIS	300	1	1.2E-3		
Lead	9.00E-6	Inappropriate for Evaluation							
Selenium	4.15E-7	2.5E-4	Selenosis	IRIS	3	1	1.7E-3		
Aluminum	1.00E-2								
Beryllium	5.80E-7	2.5E-4		IRIS	100	1	2.3E-3		
Copper	9.35E-6								
Manganese	1.12E-4	1E-2	CNS Effects	IRIS	1	1	1.0E-2		
Strontium	8.40E-6	3E-2	Rachitic Bone	IRIS	300	1	2.8E-4		
Vanadium	3.62E-5	3.5E-4		HEAST			1.0E-1		
Zinc	2.07E-5	1.5E-2	ESOD Decrease	IRIS	3	1	1.4E-3		
								3E-1	

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Table 4A-7 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	6.41E-6	3E-4	Hyperpigmentation	IRIS	3	1	2.0E-2		
Barium	6.01E-5	7E-2	Blood pressure	IRIS	3	1	8.6E-4		
Cadmium	1.03E-5	1E-3	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	1.78E-5	5E-3[2]	None given	IRIS	500	1	3.6E-3		
Nickel	1.18E-6	2E-2	Decreased weight	IRIS	300	1	5.9E-5		
Lead	8.80E-6	Inappropriate For Evaluation							
Selenium	4.06E-7	5E-3	Selenosis	IRIS	3	1	8.1E-5		
Aluminum	1.00E-2								
Beryllium	5.67E-7	5E-3		IRIS	100	1	1.1E-4		
Copper	9.14E-6								
Manganese	1.09E-4	1.4E-1	CNS Effects	IRIS	1	1	7.8E-4		
Strontium	8.22E-6	6E-1	Rachitic Bone	IRIS	300	1	1.4E-5		
Vanadium	3.54E-5	7E-3		HEAST			1.0E-2		
Zinc	2.02E-5	3E-1	ESOD Decrease	IRIS	3	1	6.7E-5		
								5E-2	
Exposure Pathway: Inhalation of Particulates[3]								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1,3]								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1,3]								2E-2	
Exposure Pathway: Ingestion of Groundwater[3]								5E-1	
									9E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Chromium VI.
[3] See Table 4-13.

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Table 4A-8. Hazard Index Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.28E-6	3E-4	Hyperpigmentation	IRIS	3	1	4.3E-3		
Barium	1.20E-5	3.5E-3	Blood pressure	IRIS	3	1	3.4E-3		
Cadmium	2.05E-6	3E-4	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	3.55E-6	2.5E-4[2]	None given	IRIS	500	1	1.0E-2		
Nickel	2.36E-7	1.0E-3	Decreased weight	IRIS	300	1	2.4E-4		
Lead	1.76E-6	Inappropriate for Evaluation							
Selenium	8.12E-8	2.5E-4	Selenosis	IRIS	3	1	3.3E-4		
Aluminum	1.01E-3								
Beryllium	1.13E-7	2.5E-4		IRIS	100	1	4.5E-4		
Copper	1.83E-6								
Manganese	2.18E-5	1E-2	CNS Effects	IRIS	1	1	2.2E-3		
Strontium	1.64E-6	3E-2	Rachitic Bone	IRIS	300	1	5.5E-5		
Vanadium	7.08E-6	3.5E-4		HEAST			2.0E-2		
Zinc	4.04E-6	1.5E-2	ESOD Decrease	IRIS	3	1	2.7E-4		
								5E-2	

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Table 4A-8 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	6.41E-6	3E-4	Hyperpigmentation	IRIS	3	1	2.0E-2		
Barium	6.01E-5	7E-2	Blood pressure	IRIS	3	1	8.6E-4		
Cadmium	1.03E-5	1E-3	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	1.78E-5	5E-3[2]	None given	IRIS	500	1	3.6E-3		
Nickel	1.18E-6	2E-2	Decreased weight	IRIS	300	1	5.9E-5		
Lead	8.80E-6	Inappropriate For Evaluation							
Selenium	4.06E-7	5E-3	Selenosis	IRIS	3	1	8.1E-5		
Aluminum	1.00E-2								
Beryllium	5.67E-7	5E-3		IRIS	100	1	1.1E-4		
Copper	9.14E-6								
Manganese	1.09E-4	1.4E-1	CNS Effects	IRIS	1	1	7.8E-4		
Strontium	8.22E-6	6E-1	Rachitic Bone	IRIS	300	1	1.4E-5		
Vanadium	3.54E-5	7E-3		HEAST			1.0E-2		
Zinc	2.02E-5	3E-1	ESOD Decrease	IRIS	3	1	6.7E-5		
								5E-2	
Exposure Pathway: Inhalation of Particulates[3]								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1,3]								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1,3]								2E-2	
Exposure Pathway: Ingestion of Groundwater[3]								4E-1	
									5E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] Chromium VI.
[3] See Table 4-14.

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4A.5.3.2 <u>Cancer Risk Estimates</u>. Cancer risk estimates for future industrial land use are presented in Table 4A-9 and 4A-10 for RME and CTE, respectively. Cancer risk for this scenario is driven by exposure to arsenic via groundwater ingestion (pathway risks of 3E-5 and 8E-6 for RME and CTE, respectively). As noted in the original assessment for Site 27, risk for this pathway is based on a single detected arsenic concentration in site groundwater that is within the background range for LHAAP (see Section 4.5.3.2). Total exposure risk estimates of 5E-5 (RME) and 1E-5 (CTE) are slightly higher than those for the site as a whole (Table 4-17) but are still well within the acceptable cancer risk range and do not indicate a concern for cancer-related health effects associated with future industrial use of this limited area of Site 27. With the exception of lead, toxicity values were available for all evaluated carcinogens resulting in increased confidence in these estimates.

4A.5.4 <u>Uncertainties Associated with Addendum Risk Estimates</u>. Most areas of uncertainty associated with original risk estimates for Site 27 would be applicable to risk characterization for this addendum. These uncertainties are discussed in Section 2.5.4.

4A.5.5 <u>Addendum Risk Summarization</u>. Total risk estimates derived as a result of addendum sampling efforts are summarized in Table 4A-11. While these values are provided in the discussion above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline assessment for a limited potential "hot spot" area at LHAAP Site 27 do not indicate any unacceptable risk to human health associated with continued current or future industrial land uses in the absence of site remediation.

4A.5.6 <u>Addendum Conclusions</u>. Objectives of this addendum to the original Site 27 baseline human health risk assessment were to conduct further supplemental risk characterization for a potential "hot spot" at the site, further evaluate the potential presence of explosives in surface soils at this limited area, evaluate the similarity between concentrations of chemical constituents in 0- to 6-inch soil depth samples with those used in original risk estimates, and expand the list of evaluated metals.

Table 4A-9. Cancer Risk Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	2.29E-6	1.5E+0	A	Various	IRIS	3.4E-6		
Lead	3.15E-6	Inappropriate For Evaluation						
Beryllium	2.03E-7	8.6E+1	B2	Various	IRIS	1.8E-5		
							2E-5	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	2.28E-6	1.5E+0	A	Various	IRIS	3.4E-6		
Lead	3.13E-6	Inappropriate For Evaluation						
Beryllium	2.02E-7	4.3E+0	B2	Various	IRIS	8.7E-7		
							4E-6	
Exposure Pathway: Inhalation of Particulates[2]							3E-8	
Exposure Pathway: Dermal Contact With Surface Waters[1, 2]							-----	
Exposure Pathway: Dermal Contact with Groundwater[1, 2]							1E-7	
Exposure Pathway: Ingestion of Groundwater[2]							3E-5	
								5E-5

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 4-15.

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Table 4A-10. Cancer Risk Estimates, Site 27 Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	1.65E-7	1.5E+0	A	Various	IRIS	2.5E-7		
Lead	2.27E-7	Inappropriate For Evaluation						
Beryllium	1.46E-8	8.6E+1	B2	Various	IRIS	1.3E-6		
							2E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	8.24E-7	1.5E+0	A	Various	IRIS	1.2E-6		
Lead	1.13E-6	Inappropriate For Evaluation						
Beryllium	7.30E-8	4.3E+0	B2	Various	IRIS	3.1E-7		
							2E-6	
Exposure Pathway: Inhalation of Particulates[2]							9E-9	
Exposure Pathway: Dermal Contact With Surface Waters[1,2]							-----	
Exposure Pathway: Dermal Contact with Groundwater[1,2]							5E-8	
Exposure Pathway: Ingestion of Groundwater[2]							8E-6	
								1E-5

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 4-16.

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Table 4A-11. Summary of Baseline Risk Estimates
Site 27 Addendum, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	9E-2	Chromium, Vanadium/Dermal Contact (Soil)
CTE	3E-2	Cadmium/Soil Ingestion
Cancer Risk		
RME	3E-6	Beryllium/Dermal Contact (Soil)
CTE	1E-6	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	9E-1	Arsenic*, Nickel/Groundwater Ingestion
CTE	5E-1	Arsenic*, Nickel/Groundwater Ingestion
Cancer Risk		
RME	5E-5	Arsenic*/Groundwater Ingestion
CTE	1E-5	Arsenic*/Groundwater Ingestion

* All concentrations within LHAAP facility background range.

Results of these additional evaluations failed to identify detectable concentrations of explosives compounds (including 2,4,6-TNT) in surface soils at this limited site area. Comparisons of metals concentrations in addendum surface soils relative to those used in previous risk evaluations yielded slightly higher values for some metals and lower values for others. While risk calculations based on addendum sampling at this limited site area were slightly higher than original estimates for the site as a whole, all estimates were within acceptable risk ranges. Based on the assumptions, approaches, methods, and uncertainties presented in this addendum, unacceptable risk to human receptors was not identified for this potential "hot spot" area at Site 27. As such, this addendum substantiates conclusions of the original assessment and fails to support the need for site remediation for protection of human health.

ECOLOGICAL ASSESSMENT

4.7 INTRODUCTION

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA 1992a). While a "stressor" may be any physical, chemical, or biological entity that induces adverse ecological response, chemicals are stressors most frequently evaluated at hazardous waste sites. This ecological assessment evaluates the potential for such response at LHAAP Site 27 (South Test Area) and was prepared in accordance with general guidance provided in USEPA (1992a; 1994).

As described in Chapter 1 of this document, ecological evaluations for all LHAAP Group 1 sites were conducted as initial screening-level assessments. It should be reemphasized that this type of assessment does not attempt to define actual site risks, but is used only to determine whether additional ecological evaluation is warranted at site. Assumptions, methods, and applicability to this type of assessment to LHAAP Site 27 are provided in this evaluation.

Remedial investigation sampling activities and results at Site 27 were presented as part of the human health evaluation earlier in this chapter. As these data also formed the basis for ecological assessment at the site, frequent reference is made to appropriate sections of the human health evaluation to prevent repetitive presentation of information applicable to both assessments.

4.8 PRELIMINARY PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

4.8.1 Environmental Setting. Site 27 covers an area of approximately 6.6 acres and exists in a remote location in the south-central portion of the plant (Figure 1-3). A map showing site topography, surface drainage patterns, suspected site limits, and other site features is presented in Figure 4-1. The site is located within the floodplain of Harrison Bayou and is covered with dense forest vegetation and undergrowth that has developed since the site was last used. While small openings in the forest canopy exist at the site, most vegetation consists of mixed pine and hardwood trees. Hardwoods include sweetgum, hackberry, several hickory species, and oaks. Also present are several species of pine. Ground cover in this area consists partially of vines such as greenbriar, poison ivy, honeysuckle, and ferns. A wide variety of terrestrial animals (Appendix A) common to upland forest habitat would be expected to inhabit the site.

Harrison Bayou is somewhat undefined in the area but is located approximately 750 feet to the east of Site 27 (Figure 1-3). No permanent creeks or streams exist on Site 27, and surface water is limited to that conveyed for short periods following rainfall events in drainage ditches transversing the site.

4.8.2 Endangered and Threatened Species. A complete listing and discussion of endangered and threatened species at LHAAP and surrounding areas are presented in the species inventory report for the facility contained in Appendix A. A review of life histories and habitat requirements for these species indicate that most would not be expected to occur at Site 27. While several of these species might occasionally use or pass through habitat at the site, the area is not known to be of prime importance to or classified as critical habitat for any of these species. None of these species are known to inhabit the site. Accordingly, significant impacts on endangered or threatened species are not anticipated in association with LHAAP Site 27.

4.8.3 Contaminants of Potential Ecological Concern. Complete details of chemical sampling activities at Site 27 are presented in the Group 1 SCSR. These activities and results are summarized in section 4.2 of this chapter. Also detailed in this section of the human health assessment is a discussion of the rationale for selection of COPC. As no detected chemicals at the site were detected in blank samples, all detected constituents were retained for human health evaluation. In a similar manner, an identical set of chemicals was used in evaluating ecological effects, and no detected constituents were eliminated from evaluation.

In summary, the only detected chemicals in Site 27 groundwater were four (4) metals (Table 4-1). While concentrations of arsenic, barium, and chromium were detected at levels within the groundwater background range for the facility, all detected concentrations of nickel (0.12 to 0.37 mg/l) exceeded the upper limits of the background range for this metal (0.02 to 0.06 mg/l). Chemicals detected in site soils were limited to metals within background ranges for the facility (Tables 4-2 and 4-3).

Due to the proximity of Harrison Bayou to the site, surface water and sediment samples were likewise collected from this system. Results of these sampling efforts are described in section 4.2.2 and Table 4-4 of this report. In summary, the only detected constituents in these samples were metals at levels approximating background conditions. Accordingly, no site-related impacts on Harrison Bayou were noted.

A review of data collected during all remedial investigations at LHAAP Site 27 reveals that the site possesses extremely low levels (if any) of soil contamination. Evidence of a chemical release to site soils is therefore questionable. However, for the sake of conservatism, ecological evaluations were completed for the site. A complete and specific list of evaluated chemicals is provided in later sections of this evaluation.

4.8.4 Site Conceptual Model for Ecological Exposure. Chemical data collected at Site 27 were evaluated in terms of potential exposure for ecological receptors. This resulted in formulation of a site-specific conceptual model for ecological exposure. Factors considered in this evaluation and the selected exposure model for Site 27 are presented below.

Detected constituents in Site 27 groundwater were limited to arsenic, barium, chromium, and nickel (Table 4-1). As noted, nickel exceeded background ranges for facility groundwater and resulted in close scrutiny for potential impacts on nearby surface waters via groundwater recharge. Despite the proximity of Harrison Bayou to Site 27, localized groundwater flow direction at the site is to the north-northeast (see Figure 6-2 of the Group 1 SCS) in a direction opposite the bayou (Figure 1-3). These findings, combined with a lack of detected contamination in bayou water and sediments (described above), preclude anticipated significant ecological exposure via groundwater recharge to this system. In addition, low levels (background concentrations) of metals detected in site soils and drainage systems from the site minimize the potential for contaminant loading to off-site aquatic systems via surface runoff. Finally, on-site surface waters are limited to those conveyed for short periods of time following rainfall events via site drainage swales and ditches. While these waters might provide brief exposure to terrestrial organisms, it is unlikely that wet/dry cycles associated with these ditches would allow establishment of permanent on-site aquatic communities. Accordingly, potential for ecological exposure to both on- and off-site aquatic receptors was considered minimal for this site, and emphasis was focused on exposure to terrestrial organisms.

Owing to the presence of metals in site soils, potential for exposure to terrestrial organisms to these contaminants via soil ingestion, direct contact, and ingestion of potentially-contaminated prey items was evaluated for this assessment. While direct contact (dermal exposure) was not evaluated for this screening-level assessment, exposure via soil and prey ingestion was considered potentially-significant. While a number of exposure scenarios involving different organisms are conceivable, maximum exposure would be expected for organisms with high prey (and associated soil) ingestion rates. As these pathways were considered most significant (and most conservative) for the site, a site conceptual model involving soil and prey ingestion for terrestrial organisms became the focus for the LHAAP Site 27 ecological assessment. For these reasons, feeding guilds represented by the least shrew and woodcock models described in Chapter 1 were evaluated for the site.

4.8.5 Screening-Level Ecotoxicity Values. Following development of a site conceptual exposure model, the next step in the screening-level ecological assessment is development of screening ecotoxicity values for chemicals of concern (USEPA 1994). As these values have not currently been tabulated for ecological effects (in a format similar to IRIS for human health assessments), this generally results in a literature search, evaluation of studies appropriate for exposure pathways and receptor species under consideration, and use of professional judgement in deriving chemical-specific toxicity values. Methodology used in developing screening-level toxicity values for all Group 1 sites was previously described in section 2.8.5 of this document (Site 1 ecological evaluation). Identical methodology and values were used in this assessment for Site 27. Resulting toxicity data for both small mammal and avian receptors for this assessment are included among those listed in Appendix C.

4.9 PRELIMINARY EXPOSURE ESTIMATE AND RISK CALCULATION

4.9.1 General. Estimation of exposure and risk calculation comprise the second step in ecological risk screening for a site. Screening-level risk estimates are obtained by comparing maximum conservative exposure levels with ecotoxicity values for species under evaluation (USEPA 1994). This evaluation conducted for LHAAP Site 27 is presented below.

4.9.2 Preliminary Exposure Estimate. Conservative exposure estimates (doses) for both the least shrew and the American woodcock for Site 27 were obtained using equations and parameter values presented in Chapter 1 of this document. As a further means of providing conservatism to intake estimates, maximum detected concentrations of all COPC in site soils and drainage ditch surface "sediments" were used in dose estimation. As noted in the human health evaluation for this site, drainage ditch soils are dry most of the time. Accordingly, these areas provide a potential source of exposure to ecological receptors in a manner similar to soils. In addition, data obtained for soil samples to a depth of five (5) feet below ground surface were evaluated for use in dose estimation. This depth range was used to account for possible exposure to deep burrowing animals and to provide ecological risk estimation for potential exposure to subsurface soils should they be exposed through site activities under a future industrial land use scenario (as described in the human health assessment). Accordingly, chemical concentrations used in intake estimations were maximum values from Tables 4-2 and 4-3.

As noted in this chapter, screening dose estimates are based on extremely conservative assumptions and parameter values. Resulting intake estimates for soil and prey ingestion for both model species are presented in the next section of this assessment.

4.9.3 Preliminary Risk Calculation. Although several approaches may be used, the hazard quotient method comparing single effect and exposure values is adequate for screening-level risk estimation (USEPA 1994). This method compares estimated exposure levels to measured or predicted threshold values for effects (RTVs as developed above). This method was used for screening-level assessment for LHAAP Site 27.

Ecological screening risk estimates derived for Site 27 least shrew and woodcock models are presented in Tables 4-18 and 4-19, respectively. Screening hazard quotients developed for each chemical of concern and species were examined for relative contribution to overall screening risk. Hazard quotients approaching or exceeding unity (1.0) received close scrutiny for ecological concern and potential further ecological evaluation.

The overall screening HI for the least shrew model for LHAAP Site 27 was estimated at 1E+1 (Table 4-18). Chemicals contributing the majority of this risk included barium, chromium, nickel, and lead with screening hazard quotients of 9E-1, 9E+0, 2E+0, and 3E-1, respectively. Accordingly, further consideration was given to interpretation of these results.

The overall screening HI for the American woodcock evaluation was estimated at 6E-1 (Table 4-19), slightly below the critical value of 1.0. While no chemical-specific hazard quotient exceeded unity, the highest estimated value was for nickel (4E-1). Accordingly, further consideration was given to interpretation of results for this metal. Avian toxicity data were not available for barium and should be considered an area of uncertainty for these estimates.

In summary, screening-level risk calculations for both the least shrew and woodcock models indicated that further interpretation of results for several metals was warranted for LHAAP Site 27. Collectively, these metals included barium, chromium, lead, and nickel.

4.9.4 Evaluation of Chemicals Driving Screening-Level Risk Estimates. Given the identification of barium, chromium, lead, and nickel as metals driving screening-level risk estimates at LHAAP Site 27, data for these constituents were further evaluated for this assessment. While not initially employed in selection of COPC for the site, this further evaluation first involved comparison with background concentrations for these metals. This evaluation provided a measure of the relative contribution of background metals to overall screening-level risk for the site. As site soils data to a depth of five (5) feet below ground surface were used for this assessment, background values for both surface and subsurface soils (USACE 1995b) were used in this evaluation. A comparison of UCLs of concentrations of these metals in site soils relative to background UCLs is presented in Table 4-20.

Table 4-18. Ecological Screening Risk Estimate For Least Shrew Model, Site 27, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Arsenic	6.5E-2	3.0E-2	9.5E-2	3.63	3E-2
Barium	1.7E+1	5.8E+1	7.5E+1	82.9	9E-1
Chromium	5.8E-1	4.3E+0	4.9E+0	0.56	9E+0
Lead	2.3E-1	1.2E+0	1.4E+0	4.6	3E-1
Mercury	2.1E-3	7.3E-3	9.4E-3	31.5	3E-4
Nickel	2.6E-1	4.5E+0	4.8E+0	2.5	2E+0
Selenium	7.8E-3	NA	7.8E-3	0.375	2E-2
				Screening Hazard Index -	1E+1

* See Appendix C. NA = Not available.

Table 4-19. Ecological Screening Risk Estimate For American Woodcock Model
Site 27, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Arsenic	9.3E-2	4.3E-2	1.4E-1	28.9	5E-3
Barium	2.4E+1	8.2E+1	1.1E+2	NA	NA
Chromium	8.2E-1	6.1E+0	6.9E+0	95	7E-2
Lead	3.3E-1	1.7E+0	2.0E+0	26	8E-2
Mercury	3.0E-3	1.0E-2	1.3E-2	0.179	7E-2
Nickel	3.7E-1	6.4E+0	6.7E+0	16.9	4E-1
Selenium	1.1E-2	NA	1.1E-2	0.49	2E-2
				Screening Hazard Index -	6E-1

* See Appendix C. NA = Not available.

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Table 4-20. Comparison of 95% Upper Confidence Limits (UCL) of Selected Metals in Soils - Site 27 Versus Background. All values are mg/Kg.

Metal	Site 27 95% UCL[1]	Background 95% UCL	
		Surface[2]	Subsurface[3]
Barium	139.23	161.8	68.7
Chromium	8.61	16.7	14.5
Nickel	5.81	4.8	8.6
Lead	6.51	14.6	6.3

[1] All soil depths to 5 feet (compare with Table 4-7).
[2] 0- to 6-inch depth (USACE 1995b).
[3] >6-inch depth (USACE 1995b).

A comparison of UCLs for these selected metals at Site 27 reveals that all four metals are present at concentrations approximating background levels (Table 4-20). Accordingly, screening-level ecological risks calculated for the site are driven by constituents present at naturally-occurring concentrations for the facility. These data fail to support evidence of a chemical release of these metals at the site, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, these metals were eliminated from further ecological evaluation at Site 27.

4.9.5 Uncertainties. Evaluation of these screening-level ecological assessment results should include consideration of areas and degrees of uncertainty associated with risk estimates (USEPA 1994). While every attempt was made to minimize areas of uncertainty with the use of conservative assumptions and estimation techniques, numerous areas of uncertainty remain and should be considered in site-related decisions. Areas of uncertainty associated with chemical sampling and analysis at Site 27 were presented in the human health evaluation (Table 4-8) and would be equally applicable to use of these data for ecological evaluation. Several additional areas of uncertainty specific to ecological evaluation are described below.

Despite the use of conservative risk estimation techniques, it is always possible that species with unknown, yet elevated sensitivities to certain chemical constituents may exist at a site. It is therefore possible that risk estimation methods may underestimate chemical-related risks for these species.

Another area of uncertainty for ecological assessment always involves use of laboratory dose-response data for estimation of ecological effects on indigenous species at a site. Uncertainties associated with use of these data are further increased by the use of a variety of safety or correction factors used to extrapolate types and degrees of biological response (e.g., chronic versus subchronic effects). Finally, the lack of toxicity data for some chemicals under evaluation often adds to uncertainty for ecological assessment. While conservative assumptions are frequently used in an attempt to mitigate these factors, these areas of uncertainty remain and should be considered in site-related decisions.

4.10 SUMMARY

A screening-level ecological risk assessment was prepared to support site management decisions for LHAAP Site 27 (South Test Area). The assessment represents an overly-conservative estimate of the potential for ecological concerns at the site and the resulting need (or lack thereof) for further ecological evaluations to support site management decisions. The assessment was conducted based on a site conceptual model of terrestrial organism exposure (using both small mammal and avian species models) to COPC in site soils.

Based on methodology used in this assessment, four (4) metals (barium, chromium, lead, and nickel) were identified as main contributors to screening-level risk estimates. Further evaluation of data for Site 27 revealed that these metals exist at concentrations approximating background levels for the facility. Accordingly, these data fail to support evidence of a chemical release of these metals to site soils, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, it is the conclusion of this screening-level assessment that little or no ecological concerns are associated with LHAAP Site 27 and that further ecological evaluations and remediation are unwarranted.

CHAPTER 5
LHAAP SITE XX
(GROUND SIGNAL TEST AREA)

HUMAN HEALTH EVALUATION

5.1 SITE DESCRIPTION

5.1.1 Site History. The Ground Signal Test Area (LHAAP Site XX) has been used intermittently since April 1963 for aerial and on-ground testing and destruction of various pyrotechnic, illuminant, and signal devices manufactured at LHAAP. The site has also been used for testing and burnout of rocket motors from a variety of missiles and, since late 1988, for the burnout of rocket motors in Pershing missiles destroyed in accordance with the Intermediate Range Nuclear Force treaty between the United States and the former Soviet Union. About 1970, a rocket motor was inadvertently destroyed when it exploded in an excavated pit near the center of the site. Debris from this explosion was reportedly placed in the resulting crater and the crater backfilled. While the site has recently been used at LHAAP, activities at the area have now ceased with the shutdown of production.

5.1.2 Site Location and Features. LHAAP Site XX is a circular area covering approximately 80 acres in the southeast portion of the plant (Figure 1-3). Access to the site is provided by an asphalt road that intersects Long Point Road just east of its intersection with Avenue Q. The eastern 70% of the site is located within the watershed of Saunder's Branch which is located approximately one-quarter mile from the eastern site boundary. The western 30% of the site lies within the watershed of Harrison Bayou, located approximately the same distance to the west. Surface runoff is conveyed to receiving waters via drainage ditches along a dirt road encircling the site. A map showing surface topography, suspected site limits, and other site features is presented later in this chapter.

Geology and hydrogeology for Site XX are described in detail in the Group 1 SCSR. In summary, surficial soils encountered across the site consist of silty clays and silts to depths of 5 to 9 feet. Groundwater was generally encountered at the site at depths ranging from approximately 10 to 15 feet below ground surface. Groundwater flow direction was calculated to be in a northerly direction with a hydraulic gradient of 0.0022 feet/foot and calculated horizontal groundwater flow velocity of 0.0016 feet/day.

5.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

5.2.1 Remedial Investigation Activities. In 1993, phase 1 remedial investigations were conducted at Site XX by Ebasco Services, Inc. (Ebasco), while phase 2 sampling activities were conducted by Sverdrup Environmental, Inc. (Sverdrup) in 1994. All information pertaining to sampling methods, boring logs, well diagrams, geotechnical data, survey information, and analytical data are provided in the Group 1 SCSR. While appropriate sections of the SCSR should be consulted for specific details, sampling activities pertinent to this baseline risk assessment are briefly summarized below.

In 1993, Ebasco collected fifteen (15) soil samples and seven (7) groundwater grab samples from seven (7) soil borings. Uppermost samples were collected from 0 to 2 feet below ground surface with the next sampling interval at 2.5 to 5 feet below ground surface. Phase 1 activities also included collection of three (3) on-site surface water and ditch soil (0- to 6-inch depth) samples from drainage ditches leading from the site to surface waters, two (2) surface water and sediment samples from Harrison Bayou, and two (2) surface water and sediment samples from Saunder's Branch. Finally, two (2) existing monitoring wells located at the site were sampled. Soil, surface water, groundwater, and sediment samples were analyzed for VOCs (EPA Method 8240); SVOCs (EPA Method 8270); explosives (EPA Method 8330); total metals, including silver, barium, cadmium, chromium, nickel, and antimony (EPA Method 6010); arsenic (EPA

Method 7060); mercury (EPA Method 7470); lead (EPA Method 7421); selenium (EPA Method 7740); and thallium (EPA Method 7841), as well as selected anions.

In 1994, Sverdrup conducted phase 2 sampling at LHAAP Site XX. Due to a high detected concentration of acetone in one soil boring during phase 1 sampling (discussed below), phase 2 sampling efforts included a soil-gas survey at five (5) sampling points around this location. Soil-gas samples were analyzed for acetone, methylene chloride, and trichloroethene. In addition, soil samples and a groundwater grab sample were collected from a confirmatory soil boring immediately adjacent to where acetone was detected in phase 1. These samples were analyzed for VOCs (EPA Method 8240). All on-site phase 1 and phase 2 sampling locations, well locations, and other pertinent site information are shown in Figure 5-1. Harrison Bayou surface water and sediment sampling locations associated with Site XX (SW/SD-01 and SW/SD-15) and those from Saunder's Branch (SW/SD-19 and SW/SD-20) are shown in Figure 4-2 in the previous chapter of this report. Other sampling sites shown in this figure were associated with LHAAP Site 27.

5.2.2 Remedial Investigation Results. Complete results of all remedial investigation sampling activities are provided in detail in the Group 1 SCSR. Results forming the basis for this risk assessment are summarized below.

Constituents detected in groundwater at LHAAP Site XX are summarized in Table 5-1. No volatile or semivolatile organic compounds or explosives were detected in groundwater samples. Detected metals included barium, lead, and nickel. Detected concentrations of these metals were within background ranges established for LHAAP groundwater (Table 5-1). While there is no current drinking water MCL for lead (but an action level of 0.015 mg/l), detected concentrations of barium and nickel were below established MCLs of 2 and 0.1 mg/l, respectively.

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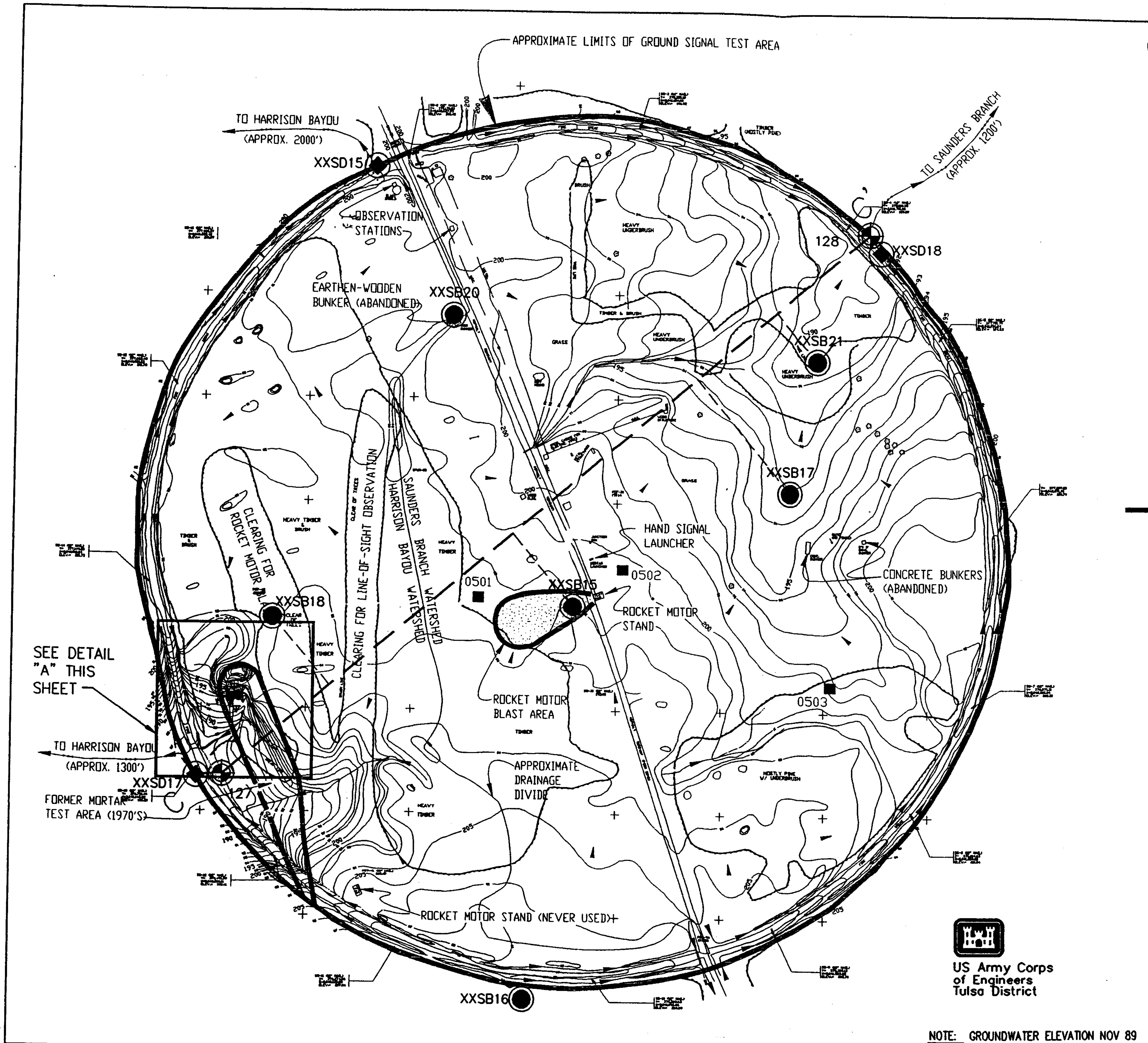

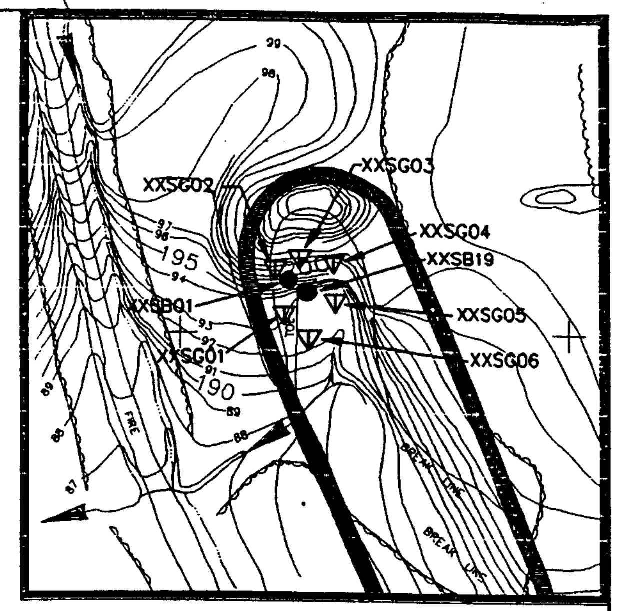

DETAIL "A"

LEGEND

- ■ SHALLOW SOIL SAMPLE (PREVIOUS)
- SURFACE WATER FLOW DIRECTION
- POINT OF COMPLIANCE
- SOIL BORING (PREVIOUS)
- SURFACE WATER/ SEDIMENT SAMPLE (PREVIOUS)
- MONITORING WELL (EXISTING)
- ● SOIL BORING (PHASE 2)
- ▽ SOIL GAS SAMPLE (PHASE 2)

250 0 250 500

SCALE IN FEET

N

US Army Corps of Engineers Tulsa District

NOTE: GROUNDWATER ELEVATION NOV 89

CORPS OF ENGINEERS, TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK. TEXAS

LHAAP XX
GROUND SIGNAL TEST AREA
SITE LAYOUT AND
SAMPLE LOCATIONS

Sverdrup Environmental

FIGURE 5-1

Table 5-1. Chemicals Detected in Groundwater
Site XX, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[1]	Sample Quantitation Limits (mg/l)	Range of Detected Concentrations (mg/l)	Background Range[2] (mg/l)
Barium	3/3	--	0.011-0.016	0.02-1.99
Lead	3/3	--	0.011-0.015	0.003-0.3
Nickel	2/3	0.05	0.05-0.06	0.02-0.06

[1] Includes quality control duplicate samples.
[2] Range of detected concentrations from Final Groundwater Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Table 5-2. Chemicals Detected In Soils[1]
Site XX, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[2]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[3]
Organics (ug/Kg)				
Acetone	2/12	12-100	124-10,300	--
Methylene Chloride	1/12	5	18	--
Metals (mg/Kg)				
Arsenic	11/11	--	1-6	1.7-36.8
Barium	11/11	--	20.2-66.7	22-287
Chromium	11/11	--	4.7-15.9	3.2-26.2
Lead	11/11	--	4-7	1.0-17.4
Mercury	6/11	0.01	0.03-0.07	0.25
Nickel	11/11	--	2.1-21.3	1.5-19.1
Selenium	7/11	0.1	0.1-0.3	0.5

[1] Includes all soil samples to depth of 5 feet.
[2] Includes quality control duplicate samples.
[3] Range of detected concentrations of both surface (0-0.5 feet) and subsurface (>0.5 foot) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Chemicals detected in Site XX soil samples at depths relevant to risk assessment evaluations are summarized in Table 5-2. This summary includes all soil samples collected at the site to a depth of five (5) feet below ground surface. This depth range is included as it was used in risk estimation for future land use scenarios for the site (explained later in this text). Seven (7) metals were detected in soil samples (Table 5-2). With the exception of a single reported concentration of nickel (21.3 mg/Kg at a depth of 3 to 5 feet in soil boring XXSB19), all detected metals were within background ranges for the facility. No explosives were detected in soils samples from Site XX.

Acetone concentrations of 124 and 10,300 ug/Kg were detected in phase 1 soil samples from boring XXSB19 at depths of 0 to 2.5 and 2.5 to 5.0 feet below ground surface, respectively. In response to this finding, a confirmatory soil-gas survey (active survey) was conducted around this location and samples from a confirmatory boring (XXSB01) were collected during phase 2 (Figure 5-1). No volatile organics were detected in any soil gas sample from this area. Methylene chloride was detected in the soil sample from XXSB01 (18 ug/Kg), but acetone was not detected (SQL was 12 ug/Kg).

Chemicals detected in on-site surface waters and ditch sediments are summarized in Table 5-3. No volatile or semivolatile organic compounds or explosives were detected in either medium. Only barium was detected in surface water (0.06 to 0.23 mg/l), and all metals concentrations in ditch sediments were within background ranges for LHAAP surface soils. These data are not indicative of accumulation or concentration of contaminants in site ditches or a high potential for off-site contaminant transport.

Chemicals detected in Harrison Bayou and Saunder's Branch surface water and sediments (0- to 6-inch depth) are summarized in Table 5-4. Due to the relative proximity of these surface waters to Site XX, these data were collected during phase 1 as an indication of potential site-related impacts on these bayous. No volatiles, semivolatiles, or explosives were detected in water

Table 5-3. Chemicals Detected in Surface Water and Ditch Surface Sediments
Site XX, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection	Sample Quantitation Limits	Range of Detected Concentrations	Background Range*
Surface Water (mg/l)				
Barium	3/3	--	0.06-0.23	--
Ditch Sediments (mg/Kg)				
Arsenic	3/3	--	1.8-2	2.3-29.7
Barium	3/3	--	23.3-64.1	35.1-287
Chromium	3/3	--	3.5-9.8	3.2-22.8
Lead	3/3	--	4-7	2.6-17.4
Mercury	3/3	--	0.01-0.03	0.25
Nickel	3/3	--	2.6-5.1	1.5-6.3
Selenium	3/3	--	0.1-0.4	0.5

* Provided for comparison - range of detected concentrations in surface soils (0-0.5-foot depth) from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

Table 5-4. Chemicals Detected in Water and Sediments of Harrison Bayou and Saunder's Branch, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[1]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[2]
Harrison Bayou				
Surface Water (mg/l)				
Barium	3/3	--	0.11-0.17	--
Sediments (mg/Kg)				
Arsenic	3/3	--	0.9-2.4	2.3-29.7
Barium	3/3	--	29.8-126	35.1-287
Chromium	3/3	--	4.1-5.5	3.2-22.8
Lead	3/3	--	5-9	2.6-17.4
Mercury	3/3	--	0.03	0.25
Nickel	3/3	--	3.7-14.7	1.5-6.3
Selenium	3/3	--	0.1-0.3	0.5
Saunder's Branch				
Surface Water (mg/l)				
Barium	2/2	--	0.09-0.43	--
Lead	1/2	--	0.006	--
Sediments (mg/Kg)				
Arsenic	2/2	--	1.0-3.5	2.3-29.7
Barium	2/2	--	27.5-85.9	35.1-287
Chromium	1/2	1.0	5.1	3.2-22.8
Lead	2/2	--	5-8	2.6-17.4
Mercury	2/2	--	0.01-0.04	0.25
Nickel	1/2	--	5.9	1.5-6.3
Selenium	2/2	--	0.1-0.3	0.5

[1] Includes quality control duplicate samples.
[2] Provided for comparison - range of detected concentrations in surface soils (0-0.5-foot depth) from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant (USACE 1995a).

or sediment samples from either drainage. Low concentrations of barium (both bayous) and lead (one sample from Saunder's Branch) were the only metals detected in surface water samples.

While not directly comparable, detected metals in Harrison Bayou and Saunder's Branch sediments were evaluated relative to surface soil background levels established for LHAAP as a reasonable approximation of potential impacts (Table 5-4). Detected concentrations in Saunder's branch were all within background levels. Nickel exceeded the surface soil background range in a single sample from Harrison Bayou (SD-01, Figure 4-2), but was within the subsurface background range (2.2 to 19.1 mg/Kg) for the facility (USACE 1995b).

5.2.3 Selection of Chemicals of Potential Concern. Environmental data sets described above were evaluated for selection of chemicals for use in quantitative risk assessment. Selection of chemicals was based on rationale described in Chapter 5 of RAGS/HHEM and discussed in Chapter 1 of this document.

Section 5.5 of RAGS/HHEM states that, under certain conditions, chemicals of concern may be eliminated based on comparison with concentrations in blank samples. Concentrations of all detected chemicals at Site XX were below SQLs in all blank samples. Therefore, no chemicals were eliminated as COPC using this protocol.

While acetone was detected in XXSB19 in phase 1 sampling, intensive confirmatory sampling during phase 2 failed to identify the presence of this common lab contaminant at this portion of the site. Lack of detection of VOCs by confirmatory sampling (including methylene chloride detected in SB01), combined with the fact that these contaminants are unlikely to have resulted from site activities, resulted in elimination of these two VOCs as contaminants of concern for quantitative risk assessment at Site XX.

While most detected chemicals were reported at levels approximating background concentrations, all detected chemicals (with the exception of those described above) were retained as COPC for evaluation of total cumulative risk at the site (as described in Chapter 1).

5.3 EXPOSURE ASSESSMENT

5.3.1 Characterization of Exposure Setting. Site XX is located in a remote portion of LHAAP. While the site has been recently used at the plant, activities have now ceased with the shut down of production. This has resulted in discontinued testing and maintenance activities in the area. The site is also a considerable distance from the plant boundary or other areas of activity resulting in minimal potential for exposure to off-site receptors.

5.3.2 Identification of Exposure Pathways. Necessary elements of an exposure pathway include a source of contamination, transport medium, routes of exposure, and human receptors at exposure points (USEPA 1989). Absence of necessary elements results in incomplete exposure pathways indicating that exposure will not occur and no adverse impacts on human health exist for that pathway.

Exposure pathways considered for evaluation for this baseline risk assessment are listed in Table 5-5. Given existing land use and activities at the site, the only conceivable current land use exposure scenario would involve recreational use of the area. While even this is extremely limited at present, occasional deer hunting (during season weekends) is allowed at LHAAP and could result in limited use of the area. It is possible that the area could be frequented by an occasional hiker, bird-watcher, or other recreationist, although current security measures at the plant preclude unlimited public access to these areas. In light of the possibility of limited current recreational activities at the site, an exposure scenario involving recreational use of the area was evaluated for this assessment.

Table 5-5. Summary of Exposure Pathways
Site XX, Longhorn Army Ammunition Plant

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
CURRENT LAND USE			
Plant Workers	Various	No	No current work activities at or near site. Pathway is incomplete.
Off-Plant Residents/ Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Dermal contact with surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Incidental ingestion of surface soils and ditch surface sediments	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Inhalation of vapors from soils and ditches	No	No volatile chemicals of potential concern.
On-Site Recreationists	Inhalation of soil and ditch particulates	Yes	Potential recreational activities at site. Pathway potentially complete.
On-Site Recreationists	Dermal contact with surface waters	Yes	Potential recreational activities at site. Short-term presence of surface waters. Pathway potentially complete.
On-Site Recreationists	Ingestion of surface waters	No	No on-site surface water of depth suitable for swimming. Pathway incomplete.
FUTURE LAND USE			
Off-Plant Residents/ Recreationists	Various	No	Distance to plant boundaries and minimal levels of contamination preclude exposure.
On-Site Recreationists	Various as listed under current land use	Yes	Potential future recreational activities at site. Pathways potentially complete.

Table 5-5 (Continued)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected For Evaluation?	Reason For Selection or Exclusion
FUTURE LAND USE (Continued)			
On-Site Workers	Dermal contact with surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Incidental ingestion of surface and subsurface soils and ditch sediments	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Inhalation of organic vapors from soils and ditches	No	No volatile chemicals of potential concern.
On-Site Workers	Inhalation of surface and subsurface soil and ditch sediment particulates	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Dermal contact with surface waters	Yes	Future industrial scenario conceivable. Pathway potentially complete.
On-Site Workers	Ingestion of surface waters	No	No conceivable activities completing this pathway.
On-Site Workers	Ingestion of groundwater from on-site well	Yes	New well installation conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Dermal contact with groundwater	Yes	Showering conceivable under industrial scenario. Pathway potentially complete.
On-Site Workers	Inhalation of volatiles from groundwater	No	No volatile compounds detected at site.
On-Site Residents	Various	No	Residential land use not conceivable. Excessed property based on availability and/or remediation to industrial use standards.

Given the overall lack of contamination at the site and failure to detect site-related contaminants in surface waters and sediments of Harrison Bayou or Saunder's Branch, exposure scenarios involving recreational receptors using these bayous were not evaluated for this assessment.

Exposure pathways under current recreational land use could include dermal contact with site soils and ditch surface sediments, incidental ingestion of surficial soils, and inhalation of soil particulates. While on-site surface waters are confined to drainage ditches encompassing the site which contain water after rainfall events, dermal contact with these waters through wading is conceivable and was evaluated for this assessment. As these waters are of insufficient depth for swimming, the potential for ingestion of surface waters while swimming was considered low and was therefore not evaluated for this site.

While future land use practices at the site could include continued recreational use, future industrial development of the area is also conceivable. The fact that the area is currently cleared of trees and has reasonable access could increase the likelihood of this land use scenario relative to other Group 1 sites. This scenario could occur as a result of construction required for mission changes at LHAAP or lease of lands for industrial development. Industrial land use could potentially include excavation of site soils for construction purposes, other earth-moving activities, and maintenance functions resulting in exposure to industrial workers.

While exposure factors (i.e., exposure duration and frequencies) would most likely differ, exposure pathways under a future industrial land use scenario could include all those described above for recreational use. Despite the existence of a current water supply source at LHAAP, it is also plausible that an on-site water supply well could be installed at the site if industrial development were to occur. This would result in the additional exposure pathways of groundwater ingestion and dermal contact with groundwater (primarily through showering) for industrial site workers. As such, these pathways were evaluated under future industrial land use conditions.

Exposed populations for all land use scenarios were assumed to be composed entirely of adults, with no sensitive subpopulations (children, elderly, etc.) present on-site. As current recreational use at the site is primarily limited to deer hunting, small children would most likely not participate in these activities. Likewise, children would not be expected at the site under a future industrial scenario. As such, risk evaluations for this assessment were conducted for adult populations only.

5.3.3 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

5.3.3.1 Summary of Exposure Concentrations. Estimates of exposure concentrations for all environmental media and exposure pathways were developed using methodology described in Chapter 1 of this report. A brief explanation of rationale used in estimating exposure concentrations for pathways involving site soils is provided below.

For purposes of exposure estimation, surface soil is generally defined as the shallowest depth that can be practically sampled (i.e., 6 inches or 1 foot) (USEPA 1989; Region VI Supplemental Guidance). Initial soil sampling at LHAAP Site XX was conducted to investigate the nature and extent of potential contamination from a variety of activities. These activities included illumination device testing, rocket motor burning, and potential burial of waste. Accordingly, soil samples of surficial materials were initially collected during phase 1 at depths of 0 to 2 or 0 to 2.5 feet below ground surface. Samples from drainage ditches were collected at depths of 0 to 6 inches below ground surface as an indication of potential transport of surface contaminants from site soils. Due to a lack of detected contamination using this approach, extensive sampling of shallower layers was not conducted during phase 2. As a result, "surface" soils data for this site were obtained from depths ranging from 0 to 6 inches to a maximum of

2 feet below ground surface. Use of these data for surface soil exposure concentration estimates adds some degree of uncertainty to these estimates, but is not considered a significant deficiency given site conditions.

Another consideration involves the use of surface materials collected from site drainage ditches in exposure estimates. These ditches represent shallow drainage pathways encompassing the site along the perimeter road which generally contain water for a short time only after rainfall events. While the term "sediment" has been applied to samples from these shallow ditches, from an exposure standpoint these surficial materials are similar to site soils in that they provide a source for release of particulates and serve as areas of potential exposure via soil ingestion and dermal contact. As the underlying basis for exposure at a site involves the use of spatially averaged soil concentrations contacted over time (USEPA 1992b), these ditches represent areas of potential soils exposure that should be accounted for in exposure estimates based on spatial averages. For these reasons, data obtained from ditches were combined with those from site soils for all pathways involving direct or indirect (through inhalation) exposure. The fact that these data are based on soil depths of 0 to 6 inches may also partially mitigate uncertainties associated with use of soils samples collected at slightly deeper depths when combined with these data for purposes of surface soil exposure estimation.

Based on rationale presented above, estimation of exposure concentrations involving site soils under current recreational land use were obtained by applying principles presented in Chapter 1 to soils data from uppermost sampling intervals in site soils and surficial ditch sediments. Estimated exposure concentrations for all site media for the current recreational land use scenario are presented in Table 5-6.

As future industrial land use could potentially involve soil excavation and earth-moving activities, the potential exists for exposure to soils at greater depths under this scenario. Accordingly, soils data from 2.5- to 5-foot depths were incorporated into these exposure estimates. Concentrations from uppermost sampling intervals and 2.5- to 5-foot depths (when

Table 5-6. Summary of Exposure Concentrations, **Current Land Use**
Site XX, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists **Incidental ingestion of soil** **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Arsenic	3.82	Concentrations are the 95% upper confidence limits or average concentrations in site surface soils and ditches assuming lognormal data distributions.
Barium	59.82	
Chromium	13.44	
Lead	6.48	
Mercury	0.04	
Nickel	5.03	
Selenium	0.33	
Recreationists **Dermal contact with surface water**		
	mg/l	
Barium	0.23	Concentration is maximum detected concentration in on-site surface waters.

present) from each soil boring were averaged to obtain a single point estimate over a 5-foot depth for that boring. These values were then combined with ditches data and exposure estimates based on the calculated 95% UCL. Exposure concentration estimates for all pathways under the future industrial land use scenario are presented in Table 5-7.

5.3.3.2 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations presented in Chapter 1. All intake equations and variable values used in intake estimates for varying exposure scenarios were presented in this chapter.

A site-specific value for the PEF used in evaluating inhalation of particulates released from site soils (see equation, Chapter 1) was likewise calculated for LHAAP Site XX using methodology presented in Section 3.3.2 of RAGS/HHEM Part B (OSWER Directive 9285.7-01B). With the exception of site dimensions, all default variable values presented in this guidance were used in this calculation. The resulting PEF for Site XX was 4.36E8 m^3/Kg.

Estimated intake rates for all COPC across all exposure pathways are presented in the "Risk Characterization" section of this document.

5.3.4 Identification of Uncertainties. Exposure assessment requires frequent use of professional judgement and estimation of variables used in risk quantification. This frequently leads to varying degrees of uncertainty in final risk estimates. Areas of uncertainty and estimated magnitude of effects of these areas in exposure assessment for this evaluation are listed in Table 5-8. These factors should always be considered in evaluating conclusions of this baseline risk assessment for LHAAP Site XX.

Table 5-7. Summary of Exposure Concentrations, **Future Land Use**
Site XX, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists		
All exposure pathways	Same as listed in Table 5-6 (Current Land Use).	
Industrial Workers		
Incidental ingestion of soil **Dermal contact with soil** **Inhalation of particulates**		
	mg/Kg	
Arsenic	3.96	Concentrations are the 95% upper confidence limits on average concentrations of ditch soils and site soils to depth of 5 feet assuming lognormal data distribution.
Barium	58.06	
Chromium	12.82	
Lead	6.34	
Mercury	0.05	
Nickel	6.02	
Selenium	0.33	
Industrial Workers		
Dermal contact with surface water		
	mg/l	
Barium	0.23	Concentration is maximum detected concentration in on-site surface waters.

Table 5-7 (Continued)

Populations/Pathways	Exposure Concentration	Comments
Industrial Workers **Ingestion of groundwater**		
	mg/l	
Barium	0.016	Concentrations are maximum detected in site groundwater.
Lead	0.015	
Nickel	0.06	

Table 5-8. Summary of Areas of Uncertainty for Exposure Assessment
Site XX, Longhorn Army Ammunition Plant

Assumption	Effect on Exposure*		
	Potential Magnitude for Over-estimation of Exposure	Potential Magnitude for Under-estimation of Exposure	Potential Magnitude for Over- or Under-estimation of Exposure
Environmental Sampling and Analysis			
Sampling locations judgmental (nonrandom). May result in bias in data.			Moderate
Sufficient sample numbers may not have been collected.		Low	
VOCs detected at site, but eliminated by verification sampling may actually be present.		Low	
Use of soil depths greater than 0-6 inches in surface exposure estimation.			Low
Exposure Parameter Estimation			
Standard assumptions used in intake calculations may not reflect actual exposure.			Moderate
Use of maximum detected values for pathways involving exposure to groundwater and surface water.	Moderate		
Installation of water supply well may not occur under future industrial land use scenario.	Low		
Exposure parameters for current recreational land use may overestimate exposure.	Low		
Use of total body surface area for dermal exposure estimates.	Moderate		

* As a general guideline, assumptions marked as "low" may affect estimates of exposures by less than one order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between one and two orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than two orders of magnitude.

An area of uncertainty in exposure assessment for this study concerns judgmental selection of soils and ditch sampling locations. This may result in bias in development of exposure concentrations for on-site human receptors. While the potential exists for over- or underestimation of exposure with use of these data, it is likely that overestimation may result due to collection of data in areas with highest potential for contamination. In addition, issues regarding use of soils data from depths greater than those frequently used for evaluating surface exposure add uncertainty to these estimates as discussed in previous sections of this report.

An additional area of uncertainty for LHAAP Site XX exposure assessment concerns elimination of acetone and methylene chloride as COPC due to failure to detect these compounds in verification sampling efforts. While these chemicals would not be expected to be associated with site activities, their elimination as chemicals of concern could result in risk underestimation if these chemicals are actually present at significant levels at the site.

As indicated in Table 5-8, many areas of uncertainty associated with this baseline risk assessment may result in overestimation of risk. This results from the practice of employing conservative assumptions throughout exposure assessment and evaluation.

5.4 TOXICITY ASSESSMENT. Toxicological information for all chemicals of potential concern at LHAAP Site XX has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this chapter. Section 2.4 should be consulted for toxicity information related to chemicals at this site.

5.5 RISK CHARACTERIZATION

5.5.1 General. The final step of the risk assessment process is risk characterization. This process involves integration of exposure assessment results and toxicity information in quantitative estimates of risk to human health. Quantified potential risk estimates are segregated by values representing both carcinogenic and noncarcinogenic health effects and are initially developed for individual chemicals via specific exposure routes. Next, risk estimates for individual chemicals (carcinogenic and noncarcinogenic) for each exposure pathway are summed to obtain total pathway risk. Finally, total pathway risks are summed, when appropriately representing total receptor exposure, to yield an estimate of total site risk for carcinogenic as well as noncarcinogenic effects. For this risk assessment, these procedures were used for risk characterization for both RME and CTE under current and future land use scenarios.

For carcinogens, "risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk)" (USEPA 1989). Risk estimates are obtained by multiplying daily intakes by published or calculated SFs. A maximum target risk range of 10^{-4} to 10^{-6} serves as a Superfund site remediation goal under the National Contingency Plan (USEPA 1989) and has generally been acknowledged as representative of acceptable risk.

Noncarcinogenic risk estimates are obtained by calculation of a non-cancer hazard quotient. The hazard quotient assumes that there is a level of exposure below which it is unlikely that even sensitive subpopulations will experience adverse health effects. If the exposure exceeds this threshold, there may be concern for potential non-cancer health effects (USEPA 1989).

Chemical-specific hazard quotients are calculated by dividing intakes by published RfDs for oral routes of exposure, or by use of calculated inhalation RfDs (explained in Chapter 1) for inhalation exposure. As in carcinogenic risk estimation, hazard quotients are then summed for individual pathways and an HI obtained. Finally, estimates of total non-cancer site risks are obtained by summing total HIs for all appropriate exposure pathways. Final HIs (as well as chemical or pathway-specific indices) in excess of unity (1.0) are an indication of possible non-cancer health concerns associated with the site.

Quantification of risks are frequently hindered by a lack of toxicological data for some site chemicals. This lack of data should always be considered in site-related decisions based on quantified risk estimation results.

Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios at LHAAP Site XX are all presented below.

5.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at Site XX are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

5.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates derived for current recreational land use at Site XX are presented in Tables 5-9 and 5-10 for RME and CTE, respectively. Evaluation of these estimates reveal that non-cancer risks are dominated by exposure to metals (principally chromium) via dermal contact with site soils (pathway HI = 2E-3) for RME and soil ingestion (pathway HI = 4E-3) for CTE. It should be noted that all detected concentrations of chromium in site soils and ditch sediments were within the facility background range for this metal (Tables 5-2 and 5-3). Total exposure HIs of 2E-2 and 1E-2 (RME and CTE, respectively) are extremely low, well below unity, and are not indicative of non-cancer health concerns for current land use at LHAAP Site XX.

5.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 5-11 and 5-12 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to arsenic via incidental ingestion of soils. As noted above, arsenic levels at the site are at background levels established for the facility. Total exposure cancer estimates of 3E-7 and 2E-7 (RME and CTE, respectively) are well within the acceptable carcinogenic risk range and do not indicate a concern for cancer-related health effects for current site land use practices.

Table 5-9. Hazard Index Estimates, Site XX, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	4.50E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.5E-3		
Barium	7.03E-6	3.5E-3	Incr. blood press.	IRIS	3	1	2.0E-3		
Chromium	1.58E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Lead	7.63E-7	Inappropriate For Evaluation							
Mercury	4.70E-9	1.5E-5	Hand tremor	EPA Reg. VI			3.1E-4		
Nickel	5.90E-7	1.0E-3	Decreased weight	IRIS	300	1	5.9E-4		
Selenium	3.88E-8	2.5E-4	Selenosis	IRIS	3	1	1.6E-4		
								1E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	8.94E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.98E-3		
Barium	1.40E-5	7E-2	Incr. blood press.	IRIS	3	1	2.00E-4		
Chromium	3.14E-6	5E-3[3]	None given	IRIS	500	1	6.28E-4		
Lead	1.52E-6	Inappropriate For Evaluation							
Mercury	9.36E-9	3E-4	Hand tremor	EPA Reg. VI			3.12E-5		
Nickel	1.18E-6	2E-2	Decreased weight	IRIS	300	1	5.90E-5		
Selenium	7.72E-8	5E-3	Selenosis	IRIS	3	1	1.54E-5		
								4E-3	

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Table 5-9 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	4.13E-10								
Barium	6.46E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.58E-4		
Chromium	1.45E-9								
Lead	7.00E-10	Inappropriate For Evaluation							
Mercury	4.32E-12	8.58E-5	Hand tremor	IRIS			5.03E-8		
Nickel	5.43E-10								
Selenium	3.56E-11								
								2E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	3.70E-6	3.5E-3	Incr. blood press.	IRIS	3	1	1.1E-3		
								1E-3	
									2E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 5-10. Hazard Index Estimates, Site XX, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	8.98E-8	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	3.0E-4		
Barium	1.41E-6	3.5E-3	Incr. blood press.	IRIS	3	1	4.0E-4		
Chromium	3.15E-7	2.5E-4[3]	None given	IRIS	500	1	1.3E-3		
Lead	1.52E-7	Inappropriate For Evaluation							
Mercury	9.40E-10	1.5E-5	Hand tremor	EPA Reg. VI			6.3E-5		
Nickel	1.18E-7	1.0E-3	Decreased weight	IRIS	300	1	1.2E-4		
Selenium	7.75E-9	2.5E-4	Selenosis	IRIS	3	1	3.1E-5		
								2E-3	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	8.94E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	2.98E-3		
Barium	1.40E-5	7E-2	Incr. blood press.	IRIS	3	1	2.00E-4		
Chromium	3.14E-6	5E-3[3]	None given	IRIS	500	1	6.28E-4		
Lead	1.52E-6	Inappropriate For Evaluation							
Mercury	9.36E-9	3E-4	Hand tremor	EPA Reg. VI			3.12E-5		
Nickel	1.18E-6	2E-2	Decreased weight	IRIS	300	1	5.90E-5		
Selenium	7.72E-8	5E-3	Selenosis	IRIS	3	1	1.54E-5		
								4E-3	

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Table 5-10 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic									
Barium	6.46E-9	4.09E-5	Incr. blood press.	EPA Reg. VI			1.58E-4		
Chromium									
Lead		Inappropriate For Evaluation							
Mercury	4.32E-12	8.58E-5	Hand tremor	IRIS			5.03E-8		
Nickel									
Selenium									
								3E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	3.70E-6	3.5E-3	Incr. blood press.	IRIS	3	1	1.1E-3		
								1E-3	
									1E-2

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 5-11. Cancer Risk Estimates, Site XX, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	6.40E-8	1.5E+0	A	Various	IRIS	9.6E-8		
Lead	1.09E-7	Inappropriate For Evaluation						
							1E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	1.28E-7	1.5E+0	A	Various	IRIS	1.9E-7		
Lead	2.17E-7	Inappropriate For Evaluation						
							2E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	5.84E-11	5E+1	A	Lung	HEAST	2.92E-9		
Lead	9.91E-11	Inappropriate For Evaluation						
							3E-9	
								3E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inihalation unit risks.

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Table 5-12. Cancer Risk Estimates, Site XX, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	1.28E-8	1.5E+0	A	Various	IRIS	1.9E-8		
Lead	2.17E-8	Inappropriate For Evaluation						
							2E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	1.28E-7	1.5E+0	A	Various	IRIS	1.9E-7		
Lead	2.17E-7	Inappropriate For Evaluation						
							2E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	5.84E-11	5E+1	A	Lung	HEAST	2.9E-9		
Lead	9.91E-11	Inappropriate For Evaluation						
							3E-9	
								2E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors callculated from inhalation unit risks.

5.5.3 <u>Future Industrial Land Use</u>. Risk estimates for future continued recreational use of Site XX would be identical to those presented above. Risk estimates developed for future industrial land use at LHAAP Site XX are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

5.5.3.1 <u>Non-Cancer Risk Estimates</u>. Non-cancer risk estimates for future industrial land use at Site XX are presented in Tables 5-13 and 5-14 for RME and CTE, respectively. For these estimates, risk is driven by dermal exposure to chromium (hazard quotient of 3E-2 for RME) and exposure to nickel via groundwater ingestion (hazard quotient of 2E-2 for CTE). This estimate is based on a maximum detected concentration of nickel in site groundwater equal to the upper limit of the background range for the facility (Table 5-1). Total site exposure HIs of 1E-1 (RME) and 4E-2 (CTE) are below the critical value of 1.0 and do not indicate concern for non-cancer health effects associated with future industrial use of LHAAP Site XX. Additionally, lead concentrations are well-below the 2,000 ppm screening level for non-residential adult exposure (see Section 2.4.2).

5.5.3.2 <u>Cancer Risk Estimates</u>. Cancer risk estimates for future industrial land use are presented in Tables 5-15 and 5-16 for RME and CTE, respectively. Cancer risk for this scenario is driven by exposure to arsenic via dermal contact with site soils (chemical-specific cancer risk of 1.0E-6) for RME and soil ingestion (3.7E-7) for CTE. As previously noted, arsenic concentrations in site soils are within background ranges for the facility. Total exposure risk estimates of 2E-6 (RME) and 5E-7 (CTE) are well within the acceptable cancer risk range, are primarily the result of exposure to background levels of naturally-occurring metals, and do not indicate a concern for cancer-related health effects associated with future industrial use of LHAAP Site XX. The inability to evaluate carcinogenic risks associated with lead exposure for all pathways should be considered an uncertainty associated with these estimates.

Table 5-13. Hazard Index Estimates, Site XX, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.98E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.0E-2		
Barium	2.90E-5	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
Chromium	6.40E-6	2.5E-4[3]	None given	IRIS	500	1	3.0E-2		
Lead	3.18E-6	Inappropriate For Evaluation							
Mercury	2.50E-8	1.5E-5	Hand tremor	EPA Reg. VI			1.7E-3		
Nickel	3.00E-6	1.0E-3	Decreased weight	IRIS	300	1	3.0E-3		
Selenium	1.65E-7	2.5E-4	Selenosis	IRIS	3	1	6.6E-4		
								5E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	1.94E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	6.5E-3		
Barium	2.84E-5	7E-2	Incr. blood press.	IRIS	3	1	4.1E-4		
Chromium	6.27E-6	5E-3[3]	None given	IRIS	500	1	1.3E-3		
Lead	3.10E-6	Inappropriate For Evaluation							
Mercury	2.45E-8	3E-4	Hand tremor	EPA Reg. VI			8.2E-5		
Nickel	2.94E-6	2E-2	Decreased weight	IRIS	300	1	1.5E-4		
Selenium	1.61E-7	5E-3	Selenosis	IRIS	3	1	3.2E-5		
								8E-3	

Table 5-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	1.78E-9								
Barium	2.61E-8	4.09E-5	Incr. blood press.	EPA Reg. VI			6.4E-4		
Chromium	5.76E-9								
Lead	2.85E-9	Inappropriate For Evaluation							
Mercury	2.25E-11	8.58E-5	Hand tremor	IRIS			2.6E-7		
Nickel	2.70E-9								
Selenium	1.48E-10								
								9E-3	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	2.00E-05	3.5E-3	Incr. blood press.	IRIS	3	1	1.0E-2		
								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Barium	6.26E-7	3.5E-3	Incr. blood press.	IRIS	3	1	1.8E-4		
Lead	2.35E-9	Inappropriate For Evaluation							
Nickel	2.35E-6	1.0E-3	Decreased weight	IRIS	300	1	2.4E-3		
								3E-3	

Table 5-13 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Barium	1.56E-4	7E-2	Incr. blood press.	IRIS	3	1	2.2E-3		
Lead	1.47E-4	Inappropriate For Evaluation							
Nickel	5.87E-4	2E-2	Decreased weight	IRIS	300	1	2.9E-2		
								3E-2	
									1E-1

[1] Intakes are dermally absorbed doses.
[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.
[3] Chromium VI.

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Table 5-14. Hazard Index Estimates, Site XX, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	3.88E-7	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	1.3E-3		
Barium	5.68E-6	3.5E-3	Incr. blood press.	IRIS	3	1	1.6E-3		
Chromium	1.25E-6	2.5E-4[3]	None given	IRIS	500	1	1.0E-2		
Lead	6.20E-7	Inappropriate For Evaluation							
Mercury	4.90E-9	1.5E-5	Hand tremor	EPA Reg. VI			3.3E-4		
Nickel	5.88E-7	1.0E-3	Decreased weight	IRIS	300	1	5.9E-4		
Selenium	3.23E-8	2.5E-4	Selenosis	IRIS	3	1	1.3E-4		
								1E-2	
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	1.94E-6	3E-4	Hyperpigmentation Vascular problems	IRIS	3	1	6.5E-3		
Barium	2.84E-5	7E-2	Incr. blood press.	IRIS	3	1	4.1E-4		
Chromium	6.27E-6	5E-3[3]	None given	IRIS	500	1	1.3E-3		
Lead	3.10E-6	Inappropriate For Evaluation							
Mercury	2.45E-8	3E-4	Hand tremor	EPA Reg. VI			8.2E-5		
Nickel	2.94E-6	2E-2	Decreased weight	IRIS	300	1	1.5E-4		
Selenium	1.61E-7	5E-3	Selenosis	IRIS	3	1	3.2E-5		
								8E-3	

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Table 5-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Inhalation of Particulates[2]									
Arsenic	1.78E-9								
Barium	2.61E-8	4.09E-5	Incr. blood press.	EPA Reg. VI			6.4E-4		
Chromium	5.76E-9								
Lead	2.85E-9	Inappropriate For Evaluation							
Mercury	2.25E-11	8.58E-5	Hand tremor	IRIS			2.6E-7		
Nickel	2.70E-9								
Selenium	1.48E-10								
								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters[1]									
Barium	3.70E-6	3.5E-3	Incr. blood press.	IRIS	3	1	1.1E-3		
								1E-3	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]									
Barium	6.26E-7	3.5E-3	Incr. blood press.	IRIS	3	1	1.8E-4		
Lead	2.35E-9	Inappropriate For Evaluation							
Nickel	2.35E-6	1.0E-3	Decreased weight	IRIS	300	1	2.4E-3		
								3E-3	

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Table 5-14 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of Groundwater									
Barium	1.10E-4	7E-2	Incr. blood press.	IRIS	3	1	1.6E-3		
Lead	1.03E-4	Inappropriate For Evaluation							
Nickel	4.11E-4	2E-2	Decreased weight	IRIS	300	1	2.1E-2		
								2E-2	
									4E-2

[1] Intakes are dermally absorbed doses.

[2] RfD (inhalation) calculated from reference concentrations (RfC) - see text.

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Table 5-15. Cancer Risk Estimates, Site XX, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	6.93E-7	1.5E+0	A	Various	IRIS	1.0E-6		
Lead	1.11E-6	Inappropriate For Evaluation						
							1E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	6.89E-7	1.5E+0	A	Various	IRIS	1.0E-6		
Lead	1.10E-6	Inappropriate For Evaluation						
							1E-6	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	6.38E-10	5E+1	A	Lung	HEAST	3.2E-8		
Lead	1.02E-9	Inappropriate For Evaluation						
							3E-8	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Lead	8.37E-10	Inappropriate For Evaluation						
Exposure Pathway: Ingestion of Groundwater								
Lead	2.07E-4	Inappropriate For Evaluation						
								2E-6

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks.

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Table 5-16. Cancer Risk Estimates, Site XX, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	4.98E-8	1.5E+0	A	Various	IRIS	7.5E-8		
Lead	7.98E-8	Inappropriate For Evaluation						
							8E-8	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	2.49E-7	1.5E+0	A	Various	IRIS	3.7E-7		
Lead	3.99E-7	Inappropriate For Evaluation						
							4E-7	
Exposure Pathway: Inhalation of Particulates[2]								
Arsenic	2.28E-10	5E+1	A	Lung	HEAST	1.1E-8		
Lead	3.66E-10	Inappropriate For Evaluation						
							1E-8	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1]								
Lead	3.01E-10	Inappropriate For Evaluation						
Exposure Pathway: Ingestion of Groundwater								
Lead	1.32E-5	Inappropriate For Evaluation						
								5E-7

[1] Intakes are dermally absorbed doses.
[2] Inhalation slope factors calculated from inhalation unit risks.

5.5.4 Uncertainties Associated with Risk Estimates. Estimates of potential risk to human health from contaminant release at LHAAP Site XX have been presented in this baseline risk assessment. Associated with these estimates are uncertainties in the risk calculation process as well as underlying assumptions forming the basis for risk evaluation. While some of these uncertainties have been briefly discussed throughout this report, further discussion of several areas of uncertainty is provided below.

As exposure via dermal contact contributed to site risk, uncertainties for this pathway were evaluated. An area of uncertainty for this pathway is the use of absorption-corrected oral toxicity data in risk characterization. While this is the approach currently recommended by the USEPA, it is recognized that use of these values may lead to considerable uncertainty and potential over- or underestimation of risk associated with dermal contact (USEPA 1992c). In addition, use of assumed skin surface areas available for contact for site receptors (Table 1-1) may overestimate or underestimate exposure under both land use scenarios and may contribute to uncertainty for estimates involving dermal contact.

Some degree of uncertainty also exists for non-cancer risk estimates for pathways involving inhalation. Reference concentrations (and resulting calculated inhalation RfDs) are lacking for many chemicals evaluated for this pathway. This area of uncertainty should be considered in interpretation of non-cancer risk estimates.

5.5.5 Risk Summarization. Total risk estimates derived as a result of this baseline risk assessment are summarized in Table 5-17. While these values are provided and discussed above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline risk assessment do not indicate any unacceptable risk to human health associated with continued current or future land uses at Site XX in the absence of site remediation.

Table 5-17. Summary of Baseline Risk Estimates
Site XX, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	2E-2	Chromium*/Dermal Contact With Soils
CTE	1E-2	Arsenic*/Soil Ingestion
Cancer Risk		
RME	3E-7	Arsenic*/Soil Ingestion
CTE	2E-7	Arsenic*/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	1E-1	Chromium*/Dermal Contact With Soils
CTE	4E-2	Nickel*/Groundwater Ingestion
Cancer Risk		
RME	2E-6	Arsenic*/Dermal Contact With Soils and Soil Ingestion
CTE	5E-7	Arsenic*/Soil Ingestion

* All concentrations within LHAAP facility background range.

5.6 SUMMARY

5.6.1 General. A baseline risk assessment was prepared to support site management decisions for LHAAP Site XX (Ground Signal Test Area). The assessment represents an estimate of potential human health impacts resulting from contaminant release from the site in the absence of remediation. Methodology used in the assessment was that prescribed by the USEPA.

5.6.2 Chemicals of Potential Concern. Chemicals of potential concern in site soils and ditch sediments included several metals at levels approximating background concentrations. Chemicals of concern in groundwater included several metals within background ranges and below drinking water MCLs. Due to failure to detect VOCs through phase 2 verification soil-gas sampling, acetone and methylene chloride were eliminated as chemicals of concern.

5.6.3 Exposure Assessment. Completed pathways for potential human exposure to site contaminants were identified for receptors under both current recreational and future industrial land use scenarios. Evaluated pathways for current recreational land use included dermal contact with soils, dermal contact with surface waters, incidental ingestion of soil, and inhalation of particulates released from site soils. For future industrial land use, the same pathways were evaluated with the addition of groundwater ingestion and dermal contact with groundwater used as a water supply source. All estimation techniques, assumptions, methodology, and degrees of uncertainty associated with risk quantification are provided in this report. As a rule, conservative assumptions were used throughout the risk assessment process where possible.

5.6.4 Risk Characterization. Risk characterization for this assessment was conducted by comparison of estimated intakes of chemicals with toxicity values for carcinogenic and noncarcinogenic health effects. Ranges of cancer and non-cancer risk estimates for both current and future land use scenarios at LHAAP Site XX are summarized in Table 5-17 of this document. Total risk estimates for both cancer and non-cancer health effects for all land use scenarios were within acceptable risk ranges.

5.6.5 Conclusion. The objective of this baseline risk assessment was to provide an estimate of risk to human health at LHAAP Site XX in the absence of remediation. Based on the assumptions, approaches, methods, and uncertainties presented in this document, unacceptable risk to human receptors was not identified. As such, this assessment fails to support the need for site remediation for protection of human health.

HUMAN HEALTH EVALUATION ADDENDUM

5A.1 INTRODUCTION AND OBJECTIVES

5A.1.1 Introduction. Following a review of Phase 1 and 2 data collected at LHAAP Site XX and human health risk characterization based on these results (as previously presented in this chapter), limited additional surface soil sampling was conducted at the site. This sampling was initiated to support additional human health risk evaluation for a limited area at Site XX identified during review of original risk assessment results. Site-specific objectives for these additional evaluations, sampling results, and resulting additional risk estimates are presented in this addendum. Addendum results are in no way meant to replace or supersede original human health risk evaluations, but are provided as supplemental information for comprehensive risk evaluation at the site.

5A.1.2 Addendum Objectives. Additional surface soil sampling at Site XX was conducted at two adjacent locations. One surface sample was collected in the former rocket motor blast area near the center of the site and the other from the nearby former mortar test area which was used during the 1970's (these areas shown in Figure 5-1). Initial objectives were to compare chemical concentrations in 0- to 6-inch soil depths and slightly deeper depths employed in original risk evaluations and to expand the list of chemical parameters for risk evaluation. While the expanded parameter list resulted in no organic chemicals of potential concern (COPC) detection, concentrations of several metals exceeded those for original results (see discussion below). Accordingly, the primary focus of this addendum became evaluation of this limited area as a potential "hot spot" for human exposure as recommended in RAGS/HHEM (USEPA 1989).

5A.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

5A.2.1 Addendum Sampling Activities. Details of surface soil sampling activities for Site XX addendum risk evaluation are described in Section 6 of the Group 1 RI Report (Volume I). In summary, one (1) surface soil (0- to 6-inch depth) sample was collected between former soil borings XXSB15 and 0501 at the former rocket motor blast area and a second surface soil sample collected near former soil boring XXSB19 (see Figure 5-1 for both locations). For quality assurance/quality control (QA/QC) purposes, one sample (sample RASSXX-01 from the former rocket motor blast area) was collected in triplicate. Sampling locations were previously shown in Figure 6-1 of the Group 1 RI report (Volume I).

All surface soil samples were analyzed for high explosives (EPA Method 8330), volatile organics (EPA Method 8260), semivolatile organics (EPA Method 8270), pesticides/PCBs (EPA Method 8080), and the 23 Target Analyte List (TAL) metals.

5A.2.2 Addendum Sampling Results. Chemicals detected in addendum surface soil samples are summarized in Table 5A-1. No explosive compounds, pesticides, or PCBs were detected in surface soil samples from the site. While no volatile compounds were detected in the field or QC duplicate sample from the rocket motor blast area, very low concentrations of two volatile compounds (methylene chloride - 2.3 ug/Kg and 1,2,4-trichlorobenzene - 1.0 ug/Kg) were reported in the QA sample analyzed by a separate laboratory. As laboratory contamination was suspected as the cause for these concentrations, the area was resampled with no reported detection of any volatile compounds (although detection limits were slightly higher at 6.78 ug/Kg for both compounds). In a similar manner, no semivolatile organic compounds were detected in

Table 5A-1. Chemicals Detected in Soils[1]
Site XX Addendum, Longhorn Army Ammunition Plant

Chemical	Frequency of Detection[2]	Sample Quantitation Limits	Range of Detected Concentrations	Background Range[3]
Metals (mg/Kg)				
Arsenic	3/3	--	4.33-73.8	2.3-29.7
Barium	3/3	--	88.1-904	35.1-287
Cadmium	3/3	--	3.63-6.95	1.25
Chromium	3/3	--	12.3-28.9J	3.2-22.8
Lead	3/3	--	9-24.0	2.6-17.4
Nickel	3/3	--	10.6-43.0	1.5-6.3
Aluminum	3/3	--	2,690-8,050	1,270-20,700
Calcium	3/3	--	250-621	124-1,090
Cobalt	1/3	2.65-2.79	3.21	1.5-19.1
Copper	3/3	--	3.19-6.21	0.88-6.7
Iron	3/3	--	3,570-13,500	2,450-31,000
Potassium	3/3	--	142-484	133-481
Magnesium	3/3	--	162-826	68.4-474
Manganese	3/3	--	37.8-567	10.9-2,330
Strontium	1/3	13.6-13.9	18.9	2.3-13.3
Vanadium	3/3	--	10.8-24.3	NA[4]
Zinc	3/3	--	6.85-17.6	3.4-16.2

[1] 0 to 6-inch depth.
[2] Includes quality control duplicate sample.
[3] Range of detected concentrations in surface (0-0.5 feet) soils from Final Soil Background Concentration Report, Longhorn Army Ammunition Plant, (USACE 1995b).
[4] Not available.

field or QC split samples from the former rocket motor blast area. While concentrations of two semivolatiles well below laboratory reporting limits (phenol - 60J ug/Kg and bis(2-ethylhexyl)phthalate - 290BJ ug/Kg) were reported for the QA sample analyzed by a separate laboratory, these results were considered the result of laboratory contamination and were therefore not considered indicative of site contamination.

Metals concentrations in addendum surface soils (Table 5A-1) were generally higher than those from original risk evaluations (Table 5-2) and exceeded background concentrations for a number of metals. While the original objective of this addendum for Site XX was comparison of results only, these findings justified further evaluation of this limited area as a potential "hot spot" for human exposure. Accordingly, risk calculations were performed for the area.

5A.2.3 Selection of Chemicals of Potential Concern. Chemicals which are essential human nutrients and present at low concentrations are generally eliminated as COPC in human health risk evaluation. These constituents commonly include iron, magnesium, calcium, and potassium (Supplemental Region VI Risk Assessment Guidance, May 1995). Accordingly, these chemicals were eliminated as COPC for this evaluation. With these exceptions, chemicals selected for use as COPC in quantitative human health risk assessment for pathways involving exposure to surface soils for this addendum included all detected chemicals listed in Table 5A-1. No other chemicals were eliminated and all were carried through to risk characterization.

5A.3 EXPOSURE ASSESSMENT

5A.3.1 Identification of Exposure Pathways. Land use assumptions and exposure pathways identical to those employed in original risk estimates (Table 5-5) were retained for this addendum. Accordingly, risk evaluations for current recreational, future recreational, and future industrial land uses and all associated exposure pathways were evaluated. These pathways are described in Section 5.3 of the original human health evaluation for Site XX.

In accordance with the objective of providing "hot spot" risk estimates for the site, quantified risks for all pathways involving dermal contact and incidental ingestion of soils were generated using only surface soil data collected for this addendum (Table 5A-1). Owing to the relatively close proximity of the two sampled areas, data from both areas were combined for "hot spot" evaluation. Conceivably, chemical intakes for receptors exclusively using this limited area would also be influenced by exposure to other environmental media (groundwater, surface waters, and fugitive dust generated across the entire site). Therefore, as a measure of total cumulative risk to human receptors, risk estimates for these pathways, as established in the original assessment, were included in risk characterization for this addendum.

5A.3.2 Quantification of Exposure. Once potentially-completed exposure pathways are identified for a risk assessment, the next step in exposure assessment is pathway-specific quantification of exposure. This step is generally conducted in two stages: (1) estimation of exposure concentrations, and (2) quantification of pathway-specific intakes for each chemical of concern (USEPA 1989).

5A.3.3. Summary of Exposure Concentrations. Exposure concentrations for all pathways involving dermal contact with soils and soil ingestion were estimated using maximum detected values (Table 5A-1). While 95% upper confidence limits (UCLs) on average concentrations in soils assuming lognormal data distributions are generally used in estimating exposure concentrations (and was used in original evaluation), small soil sample sizes for this addendum precluded use of this method. Sample size (n=2) did not permit calculation of standard deviations necessary for UCL computation. It should be emphasized that this approach adds conservatism to risk estimates.

Concentrations of COPC in soils to a depth of 5 feet were used in original exposure calculations for future industrial land use receptors (see Section 5.3.3.2). As subsurface soils were not collected for use in this addendum, data from surface soils were used in estimating exposure under industrial as well as recreational land use for this addendum. Accordingly, exposure concentrations for all pathways involving dermal contact with soils and soil ingestion for this addendum are presented in Table 5A-2.

Table 5A-2. Summary of Soil Exposure Concentrations, Current and Future Land Use, Site XX Addendum, Longhorn Army Ammunition Plant

Populations/Pathways	Exposure Concentrations	Comments
Recreationists/Industrial Workers **Incidental ingestion of soil** **Dermal contact with soil**		
	mg/Kg	
Arsenic	73.8	Concentrations are maximum detected concentrations in addendum surface soil samples. Upper confidence limits not used due to small sample sizes.
Barium	904	
Cadmium	6.95	
Chromium	28.9	
Lead	24.0	
Nickel	43.0	
Aluminum	8,050	
Cobalt	3.21	
Copper	6.21	
Manganese	567	
Strontium	18.9	
Vanadium	24.3	
Zinc	17.6	

5A.3.4 Estimation of Chemical Intakes. Chemical-specific intakes for all receptor populations and exposure pathways were calculated using intake equations and variable values employed in original risk evaluations and presented in Chapter 1. Identical values and equations were retained for use in estimating intakes for this addendum. Estimated intake rates for all COPC are presented in the "Risk Characterization" section of this addendum.

5A.3.5 Identification of Uncertainties. Most areas of uncertainty and estimated magnitude of effects in exposure assessment identified in original risk evaluations for Site XX (Section 5.3.4, Table 5-8) would be applicable to this addendum. An additional area of uncertainty would include the use of maximum detected concentrations for pathways involving soil exposure and would most likely result in overestimation of exposure for some chemicals. Similarly, uncertainty results from the use of only surface soils data for pathways involving soil exposure under future industrial land use scenarios. This may over- or underestimate exposure depending upon the extent of future excavation activities at this limited site area and relative differences between COPC concentrations in surface and subsurface soils.

5A.4 TOXICITY ASSESSMENT

Toxicological information for COPC at LHAAP Site XX has been previously provided in Section 2.4 of this document. To avoid redundancy, this information is not repeated in this addendum. Section 2.4 should be consulted for toxicity information related to chemicals of concern.

5A.5 RISK CHARACTERIZATION

5A.5.1 General. Risk characterization for this addendum was performed in an identical manner to that for the original assessment. Risk estimates (cancer and non-cancer) for both RME and CTE under current recreational and future industrial land use scenarios are all presented below.

5A.5.2 Current Recreational Land Use. Risk estimates developed for current recreational land use at the limited area of Site XX are presented in this section. Presentation of non-cancer risk estimates (RME and CTE) are followed by a discussion of carcinogenic risks (RME and CTE) for current land use.

5A.5.2.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for current recreational land use are presented in Tables 5A-3 and 5A-4 for RME and CTE, respectively. Evaluation of these estimates reveal that RME non-cancer risks are dominated by exposure to metals (principally arsenic and barium) via dermal contact with soils (pathway HI = 1E-1). Exposure to metals (principally arsenic) via soil ingestion dominated CTE non-cancer risks (pathway HI =7E-2). Total exposure HIs of 2E-1 and 1E-1 (RME and CTE, respectively) are higher than original risk estimates for the site as a whole (Table 5-17), but are still relatively low. Both estimates are below unity and are therefore not indicative of non-cancer health concerns for current land use at this limited area of Site XX.

5A.5.2.2 Cancer Risk Estimates. Cancer risk estimates for current recreational land use are presented in Tables 5A-5 and 5A-6 for RME and CTE, respectively. Carcinogenic risks are driven by exposure to arsenic via soil ingestion (chemical-specific risk = 3.7E-6 for RME and CTE). It should be noted that maximum detected arsenic concentrations form the basis for these estimates. Total exposure risk estimates of 6E-6 and 4E-6 (RME and CTE, respectively) are higher than original estimates for the site as a whole (Table 5-17) but are well within the acceptable carcinogenic risk range. These results indicate no concern for cancer-related health effects for current land use practices at this limited site area.

Table 5A-3. Hazard Index Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	8.63E-6	3E-4	Hyperpigmentation	IRIS	3	1	3.0E-2		
Barium	1.06E-4	3.5E-3	Blood pressure	IRIS	3	1	3.0E-2		
Cadmium	8.13E-7	3E-4	Proteinuria	IRIS	10	1	2.7E-3		
Chromium	3.38E-6	2.5E-4[2]	None given	IRIS	500	1	1.0E-2		
Lead	2.81E-6	Inappropriate For Evaluation							
Nickel	5.03E-6	1.0E-3	Decreased weight	IRIS	300	1	1.0E-2		
Aluminum	9.42E-4								
Cobalt	3.76E-7								
Copper	7.27E-7								
Manganese	6.63E-5	1E-2	CNS Effects	IRIS	1	1	1.0E-2		
Strontium	2.21E-6	3E-2	Rachitic Bone	IRIS	300	1	7.4E-5		
Vanadium	2.84E-6	3.5E-4		HEAST			1.0E-2		
Zinc	2.06E-6	1.5E-2	ESOD Decrease	IRIS	3	1	1.4E-4		
								1E-1	

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Table 5A-3 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	1.73E-5	3E-4	Hyperpigmentation	IRIS	3	1	6.0E-2		
Barium	2.12E-4	7E-2	Blood pressure	IRIS	3	1	3.0E-3		
Cadmium	1.63E-6	1E-3	Proteinuria	IRIS	10	1	1.6E-3		
Chromium	6.76E-6	5E-3[2]	None given	IRIS	500	1	1.4E-3		
Lead	5.62E-6	Inappropriate For Evaluation							
Nickel	1.01E-5	2E-2	Decreased weight	IRIS	300	1	5.0E-4		
Aluminum	1.88E-3								
Cobalt	7.51E-7								
Copper	1.45E-6								
Manganese	1.33E-4	1.4E-1	CNS Effects	IRIS	1	1	9.5E-4		
Strontium	4.42E-6	6E-1	Rachitic Bone	IRIS	300	1	7.4E-6		
Vanadium	5.69E-6	7E-3		HEAST			8.1E-4		
Zinc	4.12E-6	3E-1	ESOD Decrease	IRIS	3	1	1.4E-5		
								7E-2	
Exposure Pathway: Inhalation of Particulates[3]								2E-4	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1, 3]								1E-3	
									2E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency..
[2] Chromium VI.
[3] See Table 5-9.

020107

Table 5A-4. Hazard Index Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	1.73E-6	3E-4	Hyperpigmentation	IRIS	3	1	1.0E-2		
Barium	2.12E-5	3.5E-3	Blood pressure	IRIS	3	1	1.0E-2		
Cadmium	1.63E-7	3E-4	Proteinuria	IRIS	10	1	5.4E-4		
Chromium	6.79E-7	2.5E-4[2]	None given	IRIS	500	1	2.7E-3		
Lead	5.64E-7	Inappropriate For Evaluation							
Nickel	1.01E-6	1.0E-3	Decreased weight	IRIS	300	1	1.0E-3		
Aluminum	1.89E-4								
Cobalt	7.54E-8								
Copper	1.46E-7								
Manganese	1.33E-5	1E-2	CNS Effects	IRIS	1	1	1.33E-3		
Strontium	4.44E-7	3E-2	Rachitic Bone	IRIS	300	1	1.5E-5		
Vanadium	5.71E-7	3.5E-4		HEAST			1.6E-3		
Zinc	4.14E-7	1.5E-2	ESOD Decrease	IRIS	3	1	2.8E-5		
								3E-2	

020108

Table 5A-4 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	1.73E-5	3E-4	Hyperpigmentation	IRIS	3	1	6.0E-2		
Barium	2.12E-4	7E-2	Blood pressure	IRIS	3	1	3.0E-3		
Cadmium	1.63E-6	1E-3	Proteinuria	IRIS	10	1	1.6E-3		
Chromium	6.76E-6	5E-3[2]	None given	IRIS	500	1	1.4E-3		
Lead	5.62E-6	Inappropriate For Evaluation							
Nickel	1.01E-5	2E-2	Decreased weight	IRIS	300	1	5.0E-4		
Aluminum	1.88E-3								
Cobalt	7.51E-7								
Copper	1.45E-6								
Manganese	1.33E-4	1.4E-1	CNS Effects	IRIS	1	1	9.5E-4		
Strontium	4.42E-6	6E-1	Rachitic Bone	IRIS	300	1	7.4E-6		
Vanadium	5.69E-6	7E-3		HEAST			8.1E-4		
Zinc	4.12E-6	3E-1	ESOD Decrease	IRIS	3	1	1.4E-5		
								7E-2	
Exposure Pathway: Inhalation of Particulates[3]								3E-4	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1,3]								1E-3	
									1E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency..
[2] Chromium VI.
[3] See Table 5-10.

020109

Table 5A-5. Cancer Risk Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	1.24E-6	1.5E+0	A	Various	IRIS	1.9E-6		
Lead	4.03E-7	Inappropriate For Evaluation						
							2E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	2.47E-6	1.5E+0	A	Various	IRIS	3.7E-6		
Lead	8.04E-7	Inappropriate For Evaluation						
							4E-6	
Exposure Pathway: Inhalation of Particulates[2]								
							3E-9	
								6E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 5-11.

020110

Table 5A-6. Cancer Risk Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Current Recreational Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	2.47E-7	1.5E+0	A	Various	IRIS	3.7E-7		
Lead	8.04E-8	Inappropriate For Evaluation						
							4E-7	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	2.47E-6	1.5E+0	A	Various	IRIS	3.7E-6		
Lead	8.04E-7	Inappropriate For Evaluation						
							4E-6	
Exposure Pathway: Inhalation of Particulates[2]							3E-9	
								4E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 5-12.

020111

5A.5.3 Future Industrial Land Use. Risk estimates for future continued recreational use of the limited area at Site XX (represented by addendum sampling) would be identical to those presented above. Risk estimates developed for future industrial land use for this area are presented in this section. Non-cancer risk estimates are followed by carcinogenic estimates. Values for both RME and CTE are provided for both types of health effects.

5A.5.3.1 Non-Cancer Risk Estimates. Non-cancer risk estimates for future industrial land use are presented in Tables 5A-7 and 5A-8 for RME and CTE, respectively. A major contributor to total risk is exposure to arsenic and barium via dermal contact with site soils (pathway-specific hazard indices of 4E-1 and 9E-2 for RME and CTE, respectively). Total site exposure HIs of 6E-1 and 2E-1 (RME and CTE) are higher than those for original risk estimates for the site as a whole but are still below the critical value of 1.0, and therefore do not indicate concern for non-cancer health effects associated with future industrial land use of this limited area of Site XX. Conservative assumptions used in risk estimation (principally use of maximum detected values for soils and groundwater) should also be considered in evaluation of these findings.

5A.5.3.2 Cancer Risk Estimates. Cancer risk estimates for future industrial land use are presented in Table 5A-9 and 5A-10 for RME and CTE, respectively. Cancer risk for this scenario for RME exposure is driven by exposure to metals (principally arsenic) via dermal contact and soil ingestion (pathway risks of 1.9E-5 for each). For CTE exposure, cancer risk is driven by exposure to arsenic via soil ingestion (pathway risk of 7E-6). As noted above, arsenic-related risks are based on the maximum detected value. Total exposure risk estimates of 4E-5 (RME) and 8E-6 (CTE) are higher than those for the site as a whole (Table 5-17) but are still within the acceptable cancer risk range and do not indicate a concern for cancer-related health effects associated with future industrial use of this limited area of Site XX.

Table 5A-7. Hazard Index Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	3.69E-5	3E-4	Hyperpigmentation	IRIS	3	1	1.2E-1		
Barium	4.52E-4	3.5E-3	Blood pressure	IRIS	3	1	1.3E-1		
Cadmium	3.48E-6	3E-4	Proteinuria	IRIS	10	1	1.0E-2		
Chromium	1.45E-5	2.5E-4[2]	None given	IRIS	500	1	6.0E-2		
Lead	1.20E-5	Inappropriate For Evaluation							
Nickel	2.15E-5	1.0E-3	Decreased weight	IRIS	300	1	2.0E-2		
Aluminum	4.03E-3								
Cobalt	1.61E-6								
Copper	3.11E-6								
Manganese	2.84E-4	1E-2	CNS Effects	IRIS	1	1	3.0E-2		
Strontium	9.45E-6	3E-2	Rachitic Bone	IRIS	300	1	3.2E-4		
Vanadium	1.22E-5	3.5E-4		HEAST			3.0E-2		
Zinc	8.80E-6	1.5E-2	ESOD Decrease	IRIS	3	1	5.9E-4		
								4E-1	

020113

Table 5A-7 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.61E-5	3E-4	Hyperpigmentation	IRIS	3	1	1.2E-1		
Barium	4.42E-4	7E-2	Blood pressure	IRIS	3	1	1.0E-2		
Cadmium	3.40E-6	1E-3	Proteinuria	IRIS	10	1	3.4E-3		
Chromium	1.41E-5	5E-3[2]	None given	IRIS	500	1	2.8E-3		
Lead	1.17E-5	Inappropriate For Evaluation							
Nickel	2.10E-5	2E-2	Decreased weight	IRIS	300	1	1.1E-3		
Aluminum	3.94E-3								
Cobalt	1.57E-6								
Copper	3.04E-6								
Manganese	2.77E-4	1.4E-1	CNS Effects	IRIS	1	1	2.0E-3		
Strontium	9.24E-6	6E-1	Rachitic Bone	IRIS	300	1	1.5E-5		
Vanadium	1.19E-5	7E-3		HEAST			1.7E-3		
Zinc	8.61E-6	3E-1	ESOD Decrease	IRIS	3	1	2.9E-5		
								1E-1	
Exposure Pathway: Inhalation of Particulates[3]								9E-3	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1,3]								1E-2	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1,3]								3E-3	
Exposure Pathway: Ingestion of Groundwater[3]								3E-2	
									6E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency..
[2] Chromium VI.
[3] See Table 5-13.

020114

Table 5A-8. Hazard Index Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal Contact With Site Soils[1]									
Arsenic	7.22E-6	3E-4	Hyperpigmentation	IRIS	3	1	2.0E-2		
Barium	8.84E-5	3.5E-3	Blood pressure	IRIS	3	1	3.0E-2		
Cadmium	6.80E-7	3E-4	Proteinuria	IRIS	10	1	2.3E-3		
Chromium	2.83E-6	2.5E-4[2]	None given	IRIS	500	1	1.0E-2		
Lead	2.35E-6	Inappropriate For Evaluation							
Nickel	4.21E-6	1.0E-3	Decreased weight	IRIS	300	1	4.2E-3		
Aluminum	7.87E-4								
Cobalt	3.14E-7								
Copper	6.07E-7								
Manganese	5.55E-5	1E-2	CNS Effects	IRIS	1	1	1.0E-2		
Strontium	1.85E-6	3E-2	Rachitic Bone	IRIS	300	1	6.2E-5		
Vanadium	2.38E-6	3.5E-4		HEAST			1.0E-2		
Zinc	1.72E-6	1.5E-2	ESOD Decrease	IRIS	3	1	1.2E-4		
								9E-2	

020115

Table 5A-8 (Continued)

Chemical	Intake (mg/Kg-day)	RfD (mg-Kg/day)	Critical Effect	RfD Source	RfD Uncertainty Factor	RfD Modifying Factor	Hazard Quotient	Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Incidental Ingestion of Soil									
Arsenic	3.61E-5	3E-4	Hyperpigmentation	IRIS	3	1	1.2E-1		
Barium	4.42E-4	7E-2	Blood pressure	IRIS	3	1	1.0E-2		
Cadmium	3.40E-6	1E-3	Proteinuria	IRIS	10	1	3.4E-3		
Chromium	1.41E-5	5E-3[2]	None given	IRIS	500	1	2.8E-3		
Lead	1.17E-5	Inappropriate For Evaluation							
Nickel	2.10E-5	2E-2	Decreased weight	IRIS	300	1	1.1E-3		
Aluminum	3.94E-3								
Cobalt	1.57E-6								
Copper	3.04E-6								
Manganese	2.77E-4	1.4E-1	CNS Effects	IRIS	1	1	2.0E-3		
Strontium	9.24E-6	6E-1	Rachitic Bone	IRIS	300	1	1.5E-5		
Vanadium	1.19E-5	7E-3		HEAST			1.7E-3		
Zinc	8.61E-6	3E-1	ESOD Decrease	IRIS	3	1	2.9E-5		
								1E-1	
Exposure Pathway: Inhalation of Particulates[3]								6E-4	
Exposure Pathway: Dermal Contact With Surface Waters (Wading)[1, 3]								1E-3	
Exposure Pathway: Dermal Contact With Groundwater (Showering)[1, 3]								3E-3	
Exposure Pathway: Ingestion of Groundwater[3]								4E-2	
									2E-1

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency..
[2] Chromium VI.
[3] See Table 5-14.

020116

Table 5A-9. Cancer Risk Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Reasonable Maximum Exposure (RME)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	1.29E-5	1.5E+0	A	Various	IRIS	1.9E-5		
Lead	4.20E-6	Inappropriate For Evaluation						
							2E-5	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	1.28E-5	1.5E+0	A	Various	IRIS	1.9E-5		
Lead	4.18E-6	Inappropriate For Evaluation						
							2E-5	
Exposure Pathway: Inhalation of Particulates[2]							3E-8	
Exposure Pathway: Dermal Contact With Groundwater[1, 2]							-----	
Exposure Pathway: Ingestion of Groundwater[2]							-----	
								4E-5

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 5-15.

020117

Table 5A-10. Cancer Risk Estimates, Site XX Addendum, Longhorn Army Ammunition Plant, Future Industrial Land Use - Central Tendency Exposure (CTE)

Chemical	Intake (mg/Kg-day)	SF (mg-Kg/day)	Weight of Evidence	Type of Cancer	SF Source	Chemical Specific Risk	Total Pathway Risk	Total Exposure Risk
Exposure Pathway: Dermal Contact With Site Soils[1]								
Arsenic	9.30E-7	1.5E+0	A	Various	IRIS	1.4E-6		
Lead	3.02E-7	Inappropriate For Evaluation						
							1E-6	
Exposure Pathway: Incidental Ingestion of Soil								
Arsenic	4.64E-6	1.5E+0	A	Various	IRIS	7.0E-6		
Lead	1.51E-6	Inappropriate For Evaluation						
							7E-6	
Exposure Pathway: Inhalation of Particulates[2]							1E-8	
Exposure Pathway: Dermal Contact With Groundwater[1, 2]							-----	
Exposure Pathway: Ingestion of Groundwater[2]							-----	
								8E-6

[1] Intakes are dermally absorbed doses and toxicity values corrected for absorption efficiency.
[2] See Table 5-16.

020113

5A.5.4 Uncertainties Associated with Addendum Risk Estimates. Most areas of uncertainty associated with original risk estimates for Site XX would be applicable to risk characterization for this addendum. These uncertainties are discussed in Section 5.5.4.

5A.5.5 Addendum Risk Summarization. Total risk estimates derived as a result of addendum sampling efforts are summarized in Table 5A-11. While these values are provided in the discussion above, estimates are tabularized here for ease of reference and comparison. In summary, results of this baseline assessment for a limited potential "hot spot" area at LHAAP Site XX do not indicate any unacceptable risk to human health associated with continued current or future industrial land uses in the absence of site remediation.

5A.5.6 Addendum Conclusions. Objectives of this addendum to the original Site XX baseline human health risk assessment were to conduct further, supplemental risk characterization for a potential "hot spot" at the site and to expand the list of parameters for risk evaluation. While risk calculations based on addendum sampling at this limited site area were higher than original estimates for the site as a whole, all estimates were within acceptable risk ranges. Based on the assumptions, approaches, methods, and uncertainties presented in this addendum, unacceptable risk to human receptors was not identified for this potential "hot spot" area at Site XX. As such, this addendum substantiates conclusions of the original assessment and fails to support the need for site remediation for protection of human health.

Table 5A-11. Summary of Baseline Risk Estimates
Site XX Addendum, Longhorn Army Ammunition Plant

	Risk Estimate	Predominant Chemical/Pathway
Current Land Use (Recreation)		
Hazard Index		
RME	2E-1	Arsenic, Barium/Dermal Contact (Soil)
CTE	1E-1	Arsenic/Soil Ingestion
Cancer Risk		
RME	6E-6	Arsenic/Soil Ingestion
CTE	4E-6	Arsenic/Soil Ingestion
Future Land Use (Industrial)		
Hazard Index		
RME	6E-1	Arsenic, Barium/Dermal Contact (Soil)
CTE	2E-1	Arsenic/Soil Ingestion
Cancer Risk		
RME	4E-5	Arsenic/Dermal Contact, Soil Ingestion
CTE	8E-6	Arsenic/Soil Ingestion

ECOLOGICAL ASSESSMENT

5.7 INTRODUCTION

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA 1992a). While a "stressor" may be any physical, chemical, or biological entity that induces adverse ecological response, chemicals are stressors most frequently evaluated at hazardous waste sites. This ecological assessment evaluates the potential for such response at LHAAP Site XX (Ground Signal Test Area) and was prepared in accordance with general guidance provided in USEPA (1992a; 1994).

As described in Chapter 1 of this document, ecological evaluations for all LHAAP Group 1 sites were conducted as initial screening-level assessments. It should be reemphasized that this type of assessment does not attempt to define actual site risks, but is used only to determine whether additional ecological evaluation is warranted at site. Assumptions, methods, and applicability to this type of assessment to LHAAP Site XX are provided in this evaluation.

Remedial investigation sampling activities and results at Site XX were presented as part of the human health evaluation earlier in this chapter. As these data also formed the basis for ecological assessment at the site, frequent reference is made to appropriate sections of the human health evaluation to prevent repetitive presentation of information applicable to both assessments.

5.8 PRELIMINARY PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

5.8.1 Environmental Setting. Site XX is a circular area covering approximately 80 acres in the southeast portion of LHAAP (Figure 1-3). A map showing site topography, surface drainage patterns, suspected site limits, and other site features is presented in Figure 5-1. The site is centrally-located between Harrison Bayou (approximately 1,300 feet to the west) and Saunder's Branch (approximately 1,200 feet to the east) (Figure 1-3). The eastern two-thirds of the site are within the Saunder's Branch watershed while the western one-third drains to Harrison Bayou. Surface runoff is conveyed to receiving waters via drainage ditches along a dirt road encircling the site.

While habitat at Site XX includes scattered stands of timber (mixed pine/hardwoods), the central portion of the site consists of grasslands which were historically mowed for fire prevention during testing activities at LHAAP. Vegetation species present in this area include wiregrass, broomsedge, and blue stem. Also present at the site are a mixture of upland shrub/scrub species, including sumac, plums, and hawthorne. Due to the diversity of habitat at the site, a wide variety of terrestrial animals (Appendix A) common to grasslands, mixed pine/hardwood forest, and shrub/scrub thickets would be expected to inhabit the site.

No permanent creeks or streams exist on Site XX, and surface water is limited to that conveyed for short periods following rainfall events in drainage ditches encircling the site.

5.8.2 Endangered and Threatened Species. A complete listing and discussion of endangered and threatened species at LHAAP and surrounding areas are presented in the species inventory report for the facility contained in Appendix A. A review of life histories and habitat requirements for these species indicate that most would not be expected to occur at Site XX. While several of these species might occasionally use or pass through habitat at the site, the area is not known to be of prime importance to, or classified as critical habitat for any of these species. None of these species are known to inhabit the site. Accordingly, significant impacts on endangered or threatened species are not anticipated in association with LHAAP Site XX.

5.8.3 Contaminants of Potential Ecological Concern. Complete details of chemical sampling activities at Site XX are presented in the Group 1 SCSR. These activities and results are likewise summarized in section 5.2 of this chapter. Also detailed in this section of the human health assessment is a discussion of the rationale for selection of COPC. As no detected chemicals at the site were reported in blank samples, no constituents were eliminated based on blank sample results. While two VOCs (acetone and methylene chloride) were detected in site soils, confirmatory sampling for these compounds failed to verify their presence. These chemicals were therefore eliminated as chemicals of concern as described in section 5.2.3. With the exception of these two common lab contaminants, all detected constituents were retained for human health evaluation. In a similar manner, an identical set of chemicals was used in evaluating ecological effects.

In summary, the only detected chemicals in Site XX groundwater were barium, lead, and nickel (Table 5-1). All detected concentrations of these metals were within background ranges for the facility. With the exception of the two (2) VOCs described above, chemicals detected in site soils and drainage ditches were limited to metals within background ranges for the facility (Tables 5-2 and 5-3).

Owing to proximities of Harrison Bayou and Saunder's Branch to the site, surface water and sediment samples were likewise collected from these systems. Results of these sampling efforts are described in section 5.2.2 and Table 5-4 of this report. In summary, the only detected constituents in these samples were metals at levels approximating background conditions. Accordingly, no site-related impacts on Harrison Bayou and/or Saunder's Branch were noted during remedial investigation sampling activities.

A review of data collected during all remedial investigations at LHAAP Site XX reveals that the site possesses extremely low levels (if any) of soil contamination. Evidence of a chemical release to site soils is therefore questionable. However, for the sake of conservatism, ecological evaluations were completed for the site. A complete and specific list of evaluated chemicals is provided in later sections of this evaluation.

5.8.4 Site Conceptual Model for Ecological Exposure. Chemical data collected at Site XX were evaluated in terms of potential exposure for ecological receptors. This resulted in formulation of a site-specific conceptual model for ecological exposure. Factors considered in this evaluation and the selected exposure model for Site XX are presented below.

Detected constituents in Site XX groundwater were limited to barium, lead, and nickel at background concentrations (Table 5-1). Accordingly, ecological impacts resulting from groundwater inputs to surface waters are not anticipated. In addition, low levels (background concentrations) of metals detected in site soils and drainage systems from the site minimize the potential for contaminant loading to off-site aquatic systems via surface runoff. Sampling results from the two bayous adjacent to Site XX support these assumptions. Finally, on-site surface waters are limited to those conveyed for short periods of time following rainfall events via site drainage swales and ditches. While these waters might provide brief exposure to terrestrial organisms, it is unlikely that wet/dry cycles associated with these ditches would allow establishment of permanent on-site aquatic communities. Accordingly, potential for ecological exposure to both on- and off-site aquatic receptors was considered minimal for this site, and emphasis was focused on exposure to terrestrial organisms.

Owing to the presence of metals in site soils, potential for exposure to terrestrial organisms to these contaminants via soil ingestion, direct contact, and ingestion of potentially-contaminated prey items was evaluated for this assessment. While direct contact (dermal exposure) was not evaluated for this screening-level assessment, exposure via soil and prey ingestion was considered potentially-significant. While a number of exposure scenarios involving different organisms are conceivable, maximum exposure would be expected for organisms with high prey (and associated soil) ingestion rates. As these pathways were considered most significant (and most conservative) for the site, a site conceptual model involving soil and prey ingestion for terrestrial organisms became the focus for the LHAAP Site XX ecological assessment. For these reasons, feeding guilds represented by the least shrew and woodcock models described in Chapter 1 were evaluated for the site.

5.8.5 Screening-Level Ecotoxicity Values. Following development of a site conceptual exposure model, the next step in the screening-level ecological assessment is development of screening ecotoxicity values for chemicals of concern (USEPA 1994). As these values have not currently been tabulated for ecological effects (in a format similar to IRIS for human health assessments), this generally results in a literature search, evaluation of studies appropriate for exposure pathways and receptor species under consideration, and use of professional judgement in deriving chemical-specific toxicity values. Methodology used in developing screening-level toxicity values for all Group 1 sites was previously described in section 2.8.5 of this document (Site 1 ecological evaluation). Identical methodology and values were used in this assessment for Site XX. Resulting toxicity data for both small mammal and avian receptors for this assessment are included among those listed in Appendix C.

5.9 PRELIMINARY EXPOSURE ESTIMATE AND RISK CALCULATION

5.9.1 General. Estimation of exposure and risk calculation comprise the second step in ecological risk screening for a site. Screening-level risk estimates are obtained by comparing maximum, conservative exposure levels with ecotoxicity values for species under evaluation (USEPA 1994). This evaluation conducted for LHAAP Site XX is presented below.

5.9.2 Preliminary Exposure Estimate. Conservative exposure estimates (doses) for both the least shrew and the American woodcock for Site XX were obtained using equations and parameter values presented in Chapter 1 of this document. As a further means of providing conservatism to intake estimates, maximum detected concentrations of all COPC in site soils and drainage ditch surface "sediments" were used in dose estimation. As noted in the human health evaluation for this site, drainage ditch soils are dry most of the time. Accordingly, these areas provide a potential source of exposure to ecological receptors in a manner similar to soils. In addition, data obtained for soil samples to a depth of five (5) feet below ground surface were evaluated for use in dose estimation. This depth range was used to account for possible exposure to deep burrowing animals and to provide for ecological risk estimation for potential exposure to subsurface soils should they be exposed through site activities under a future industrial land use scenario (as described in the human health assessment). Accordingly, chemical concentrations used in intake estimations were maximum values from Tables 5-2 and 5-3.

As noted in this chapter, screening dose estimates are based on extremely conservative assumptions and parameter values. Resulting intake estimates for soil and prey ingestion for both model species are presented in the next section of this assessment.

5.9.3 Preliminary Risk Calculation. Although several approaches may be used, the hazard quotient method comparing single effect and exposure values is adequate for screening-level risk estimation (USEPA 1994). This method compares estimated exposure levels to measured or predicted threshold values for effects (RTVs as developed above). This method was used for screening-level assessment for LHAAP Site XX.

Ecological screening risk estimates derived for Site XX least shrew and woodcock models are presented in Tables 5-18 and 5-19, respectively. Screening hazard quotients developed for each chemical of concern and species were examined for relative contribution to overall screening risk. Hazard quotients approaching or exceeding unity (1.0) received close scrutiny for ecological concern and potential further ecological evaluation.

The overall screening HI for the least shrew model for LHAAP Site XX was estimated at 1E+1 (Table 5-18). Chemicals contributing the majority of this risk included chromium and nickel with screening hazard quotients of 6E+0 and 4E+0, respectively. Accordingly, further consideration was given to interpretation of these results.

The overall screening HI for the American woodcock evaluation was estimated at 1E+0 (Table 5-19), equaling the critical value of 1.0. While no chemical-specific hazard quotient exceeded unity, the highest estimated value was for nickel (9E-1). Accordingly, further consideration was given to interpretation of results for this metal. Avian toxicity data were not available for barium and should be considered an area of uncertainty for these estimates.

Table 5-18. Ecological Screening Risk Estimate For Least Shrew Model, Site XX, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Arsenic	1.6E-1	7.2E-2	2.3E-1	3.63	6E-2
Barium	1.7E+0	6.0E+0	7.7E+0	82.9	9E-2
Chromium	4.1E-1	3.0E+0	3.4E+0	0.56	6E+0
Lead	1.8E-1	9.3E-1	1.1E+0	4.6	2E-1
Mercury	1.8E-3	6.4E-3	8.2E-3	31.5	3E-4
Nickel	5.5E-1	9.6E+0	1.0E+1	2.5	4E+0
Selenium	1.0E-2	NA	1.0E-2	0.375	3E-2
				Screening Hazard Index -	1E+1

* See Appendix C. NA = Not available.

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Table 5-19. Ecological Screening Risk Estimate For American Woodcock Model
Site XX, Longhorn Army Ammunition Plant

Chemical	Soil Ingestion Dose (mg/Kg-day)	Earthworm Ingestion Dose (mg/Kg-day)	Total Ingestion Dose (mg/Kg-day)	Reference Toxicity Value* (mg/Kg-day)	Screening Hazard Quotient
Arsenic	2.2E-1	1.0E-1	3.2E-1	28.9	1E-2
Barium	2.5E+0	8.5E+0	1.1E+1	NA	NA
Chromium	5.9E-1	4.4E+0	5.0E+0	95	5E-2
Lead	2.6E-1	1.3E+0	1.6E+0	26	6E-2
Mercury	2.6E-3	9.1E-3	1.2E-2	0.179	7E-2
Nickel	7.9E-1	1.4E+1	1.5E+1	16.9	9E-1
Selenium	1.5E-2	NA	1.5E-2	0.49	3E-2
				Screening Hazard Index -	1E+0

* See Appendix C. NA = Not available.

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In summary, screening-level risk calculations for both the least shrew and woodcock models indicated that further interpretation of results for several metals was warranted for LHAAP Site XX. Collectively, these metals were limited to chromium and nickel.

5.9.4 Evaluation of Chemicals Driving Screening-Level Risk Estimates. Given the identification of chromium and nickel as metals driving screening-level risk estimates at LHAAP Site XX, data for these constituents were further evaluated for this assessment. While not initially employed in selection of chemicals of potential concern for the site, this further evaluation first involved comparison with background concentrations for these metals. This evaluation provided a measure of the relative contribution of background metals to overall screening-level risk for the site. As site soils data to a depth of five (5) feet below ground surface were used for this assessment, background values for both surface and subsurface soils (USACE 1995b) were used in this evaluation. A comparison of UCLs of these metals in site soils relative to background UCLs is presented in Table 5-20. This approach was used to facilitate comparison of reasonable exposure-relevant metals concentrations for the site with those in background soils.

Table 5-20. Comparison of 95% Upper Confidence Limits (UCL) of Selected Metals in Soils - Site XX Versus Background. All values are mg/Kg.

Metal	Site XX 95% UCL[1]	Background 95% UCL	
		Surface[2]	Subsurface[3]
Chromium	12.82	16.7	14.5
Nickel	6.02	4.8	8.6

[1] All soil depths to 5 feet (compare with Table 5-6).
[2] 0- to 6-inch depth (USACE 1995b).
[3] >6-inch depth (USACE 1995b).

A comparison of UCLs for these selected metals at Site XX reveals that both chromium and nickel are present at concentrations approximating background levels (Table 5-20). Accordingly, screening-level ecological risks calculated for the site are driven by constituents present at naturally-occurring concentrations for the facility. These data fail to support evidence of a chemical release of these metals at the site, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, these metals were eliminated from further ecological evaluation at Site XX.

5.9.5 Uncertainties. Evaluation of these screening-level ecological assessment results should include consideration of areas and degrees of uncertainty associated with risk estimates (USEPA 1994). While every attempt was made to minimize areas of uncertainty with the use of conservative assumptions and estimation techniques, numerous areas of uncertainty remain and should be considered in site-related decisions. Areas of uncertainty associated with chemical sampling and analysis at Site XX were presented in the human health evaluation (Table 5-8) and would be equally applicable to use of these data for ecological evaluation. Several additional areas of uncertainty specific to ecological evaluation are described below.

Despite the use of conservative risk estimation techniques, it is always possible that species with unknown, yet elevated sensitivities to certain chemical constituents may exist at a site. It is therefore possible that risk estimation methods may underestimate chemical-related risks for these species.

Another area of uncertainty for ecological assessment always involves use of laboratory dose-response data for estimation of ecological effects on indigenous species at a site. Uncertainties associated with use of these data are further increased by the use of a variety of safety or correction factors used to extrapolate types and degrees of biological response (e.g., chronic versus subchronic effects). Finally, the lack of toxicity data for some chemicals under evaluation often adds to uncertainty for ecological assessment. While conservative assumptions are frequently used in an attempt to mitigate these factors, these areas of uncertainty remain and should be considered in site-related decisions.

5.10 SUMMARY

A screening-level ecological risk assessment was prepared to support site management decisions for LHAAP Site XX (Ground Signal Test Area). The assessment represents a conservative estimate of the potential for ecological concerns at the site and the resulting need (or lack thereof) for further ecological evaluations to support site management decisions. The assessment was conducted based on a site conceptual model of terrestrial organism exposure (using both small mammal and avian species models) to chemicals of potential concern in site soils.

Based on methodology used in this assessment, two (2) metals (chromium and nickel) were identified as main contributors to screening-level risk estimates. Further evaluation of data for Site XX revealed that these metals exist at concentrations approximating background levels for the facility. Accordingly, these data fail to support evidence of a chemical release of these metals to site soils, serve to illustrate the conservative nature of methodology used in this assessment, and indicate that potential remedial actions would not result in risk reduction for ecological receptors below that present under background conditions. As such, it is the conclusion of this screening-level assessment that little or no ecological concerns are associated with LHAAP Site XX and that further ecological evaluations and remediation are unwarranted.

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APPENDIX A

LONGHORN ARMY AMMUNITION PLANT SPECIES INVENTORY

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CADDO LAKE INSTITUTE
INITIAL SPECIES INVENTORY FOR
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

COMPLETION REPORT FOR CONTRACT DACA56-94-M-0985
TULSA DISTRICT, CORPS OF ENGINEERS

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JUNE, 1995

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EXECUTIVE SUMMARY

This document summarizes ecological information collected at Longhorn Army Ammunition Plant at Karnack, Texas, beginning in the fall of 1995 by The Caddo Lake Institute. Included in the document is a characterization of the 8500 acre facility and supporting documentation. Data include a vegetation analysis, vertebrate animals that probably inhabit the area and their estimated abundances, and a discussion of endangered and threatened species. In general the methods of data collection included consultation with agency personnel and private consultants, utilization of published materials and geographical information systems, and limited on-site visits.

Results of the study showed that the property is approximately 85% forested with mixed pine-hardwood forests being the most common, followed by pine forests and bottomland hardwood forests. Other vegetation types including shrub-scrub, grassland, marsh, and mixed swamp are relatively rare. Listings by vertebrate class of the probable species either on LHAAP or in the adjacent Caddo Lake is provided. The fish fauna of LHAAP has not been studied, so the list provided is for species collected from Caddo Lake. For the other vertebrate classes, the lists were compiled based on personal observations and published works. The total number of vertebrate species was estimated at 465, which represents 38% of the total vertebrate species reported from the state of Texas. Of these species, 21 are listed on either federal or state endangered or threatened lists or both. There is good evidence that 11 of the 21 species have been on or in the immediate vicinity of LHAAP. Because the Harrison Bayou area of LHAAP has been designated a special protected area, a detailed description of that area is included.

INITIAL SPECIES INVENTORY FOR LONGHORN ARMY AMMUNITION PLANT KARNACK, TEXAS

COMPLETION REPORT FOR CONTRACT DACA56-94-M-0985 TULSA DISTRICT, CORPS OF ENGINEERS

INTRODUCTION

The following is the final report to the Tulsa District, U.S. Army Corps of Engineers completing contract DACA56-94-M-D985 to The Caddo Lake Institute, Inc. An initial biological species inventory was conducted for the Longhorn Army Ammunition Plant (LHAAP) and Caddo Lake, Texas and Louisiana, during the fall of 1994 and winter of 1995.

SCOPE OF WORK

The Scope of Work required the completion of three tasks:

(1) Completion of an inventory of probable vertebrate animal species inhabiting terrestrial and aquatic habitats (bayous, creeks, streams) at LHAAP and adjacent Caddo Lake. This inventory will include species lists organized by vertebrate class and will provide both common and scientific names of each species. In addition, each species will be designated as "abundant", "common", or "rare" with respect to occurrence in the areas of interest. Methods of acquiring this information will include consultation with various resource agency personnel and records, review of past biological studies, documents, and limited on-site observation and/or sampling.

(2) Completion of an inventory of all Federal and State threatened or endangered species likely to inhabit LHAAP and/or Caddo Lake. A brief description of habitat requirements and life history will also be provided for each of these species. The primary method of completing this task will be consultation with agencies responsible for publishing and maintaining this information.

(3) Preparation of a general description of major plant assemblages present at LHAAP and Caddo Lake. A complete inventory of all plant species is not required under this task but discussion should be provided for dominant species comprising each major assemblage type (i.e., coniferous forest, grasslands, bottomland hardwood forest, wetlands, etc.)

PERSONNEL INVOLVED WITH THE STUDY

CADDO LAKE INSTITUTE	
Dwight K. Shellman, Jr.	President
Dr. Roy Darville	Project Director
Greg Brock	landscape characterization
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Jamey Johnston	GPS and GIS Technician
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CONSULTANTS	
Tom Brantley	forestry
Doug Hine	vegetation

GENERAL DESCRIPTION OF THE STUDY AREA

Established in October 1942, Longhorn Army Ammunition Plant consists of 8483 acres located adjacent to the communities of Karnack, Uncertain, and the western shore of Caddo Lake in Harrison County in northeast Texas. LHAAP is 14 miles northeast of Marshall, Texas and 40 miles west of Shreveport, Louisiana. The site is owned by the federal government and operated by Thiokol Corporation under the jurisdiction of the U.S. Army Armaments, Munitions, and Chemical Command. The boundary of the property is delineated by fencing and Caddo Lake.

LHAAP is within the Pineywoods vegetational area of Gould (1975) and has a subtropical humid climate characterized by warm and humid summers with an average annual low temperature of 11°C and the average annual high temperature of 22°C (Larkin and Bomar 1983). The City of Marshall receives an average annual rainfall of 46.9 inches with about 50% of that falling between April and September (Golden et al. 1994). The elevation varies from normal pool level of 168.5 feet at Caddo Lake to 335 feet at Haynes Cemetery (USGS 1978). The area is characterized by a variety of habitats that support a diverse flora and fauna assemblage. An excellent overview of the habitats of the Cypress Bayou Basin in Texas and Louisiana can be found in Cloud (1995).

LHAAP lies on the shore of Caddo Lake in the Cypress Bayou watershed, which occupies about 6000 square miles in all or part of 11 Texas counties and one Louisiana parish. Caddo Lake, occupying about 25,000 surface areas, is the centerpiece of the watershed. Caddo Lake has a rich and varied history with extensive use by Native Americans and Europeans. In 1993 Caddo Lake was designated a "Wetland of International Significance" by the Ramsar Bureau in Gland, Switzerland. The U.S. Fish and Wildlife Service also recently classified the area, including parts of LHAAP's bottomland hardwoods, as a Resource Category 1 Habitat under the Fish and Wildlife Coordination Act, the most highly-valued classification of wetlands in the United States. Thus, LHAAP is an area that is noted for its biodiversity and uniqueness.

TASK 1
INVENTORY OF PROBABLE VERTEBRATE ANIMAL SPECIES

The following is an inventory of probable vertebrate animal species inhabiting terrestrial and aquatic habitats at LHAAP and adjacent Caddo Lake. The inventory is organized by vertebrate class and includes the common and scientific name of each species and its probable abundance (A = abundant, C = common, and R = rare) when it could be estimated for LHAAP. In general, the methods of obtaining these data involved examination of published scientific works and the consultation with agency personnel and private consultants in the area. More specific methods are given at the beginning of each list.

CLASSES AGNATHA AND OSTEICHTHYES

The following species of fish were collected over the past 41 years at Caddo Lake by personnel of the Inland Fisheries Branch of the Texas Parks and Wildlife Department (TPWD) (Darville and Brock 1993b). Fish were collected by a variety of methods, including seining, electrofishing, gill netting and frame netting. A total of 71 species of fish were collected during this time period. Catch per unit effort, age, average length and other data are available from TPWD. As far as is known, there is no fish species list available for any drainage on LHAAP. Of course, species composition in streams would vary somewhat from those occurring in the adjacent lake. As far is known there are no abundances known for fish species in Caddo Lake. Nomenclature follows Hubbs et al. (1991).

Common Name	Scientific Name
Chestnut Lamprey	*Ichthyomyzon castaneus*
Alligator Gar	*Lepisosteus spatula*
Shortnose Gar	*Lepisosteus platostomus*
Spotted Gar	*Lepisosteus oculatus*
Longnose Gar	*Lepisosteus osseus*
Bowfin	*Amia calva*
Skipjack Herring	*Alosa chrysochloris*
Threadfin Shad	*Dorosoma petenense*
Gizzard Shad	*Dorosoma cepedianum*
Grass Pickerel	*Esox americanus*
Chain Pickerel	*Esox niger*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Smallmouth Buffalo	*Ictiobus bubalus*
River Carpsucker	*Carpiodes carpio*

Common Name	Scientific Name
Spotted Sucker	*Minytrema melanops*
Lake Chubsucker	*Erimyzon sucetta*
Common Carp	*Cyprinus carpio*
Golden Shiner	*Notemigonus crysoleucas*
Pugnose Minnow	*Opsopoeodus emiliae*
Ironcolor Shiner	*Notropis chalybaeus*
Weed Shiner	*Notropis texanus*
Pallid Shiner	*Notropis amnis*
Blacktail Shiner	*Cyprinella venusta*
Red Shiner	*Cyprinella lutrensis*
Sand Shiner	*Notropis stramineus*
Blackspot Shiner	*Notropis atrocaudalis*
Mimic Shiner	*Notropis volucellus*
Taillight Shiner	*Notropis maculatus*
Silvery Minnow	*Hybognathus nuchalis*
Bullhead Minnow	*Pimephales vigilax*
Channel Catfish	*Ictalurus punctatus*
Blue Catfish	*Ictalurus furcatus*
Black Bullhead	*Ameriurus melas*
Yellow Bullhead	*Ameriurus natalis*
Brown Bullhead	*Ictalurus nebulosus*
Flathead Catfish	*Pylodictis olivaris*
Tadpole Madtom	*Noturus gyrinus*
American Eel	*Anguilla rostrata*
Golden Topminnow	*Fundulus chrysotus*
Starhead Topminnow	*Fundulus dispari*
Blackstripe Topminnow	*Fundulus notatus*
Pirate Perch	*Aphredoderus sayanus*
Mosquitofish	*Gambusia affinis*
Mississippi Silverside	*Menidia audens*
Brook Silverside	*Labidesthes sicculus*
White Bass	*Morone chrysops*
Yellow Bass	*Morone mississippiensis*
Spotted Bass	*Micropterus punctulatus*
Largemouth Bass	*Micropterus salmoides*
Warmouth	*Lepomis gulosus*
Bantam Sunfish	*Lepomis symmetricus*
Spotted Sunfish	*Lepomis punctuatus*
Redear Sunfish	*Lepomis microlophus*
Bluegill Sunfish	*Lepomis macrochirus*
Redbreast Sunfish	*Lepomis auritus*
Longear Sunfish	*Lepomis megalotis*
Dollar Sunfish	*Lepomis marginatus*
White Crappie	*Pomoxis annularis*
Black Crappie	*Pomoxis nigromaculatus*
Flier	*Centrarchus macropterus*
Banded Pygmy Sunfish	*Elassoma zonatum*
River Darter	*Percina shumardi*
Logperch	*Percina caprodes*

Common Name	Scientific Name
Scaly Sand Darter	*Ammocrypta vivax*
Bluntnose Darter	*Etheostoma chlorosomum*
Slough Darter	*Etheostoma gracile*
Scalyhead Darter	*Etheostoma barratti*
Cypress Darter	*Etheostoma proeliare*
Fountain Darter	*Etheostoma fonticola*
Freshwater Drum	*Aplodinotus grunniens*

CLASS AMPHIBIA

Hardy (1994) of Louisiana State University at Shreveport is in the process of surveying 53 regional collections for amphibian specimens. He lists 29 species of amphibians that have been collected from the Caddo Lake drainage system. Campo (1986) of the TPWD lists two species. Using the range data from museum collections and a literature review, Dixon (1987) reported that there could be 26 species in Harrison or Marion Counties, including three not listed by Hardy. Tom Brantley, former forester at LHAAP, kept few records of amphibians at LHAAP. The abundances in this table are based on Brantely (1995). Based on these surveys a total of 31 species could inhabit LHAAP. Nomenclature follows that of Dixon (1987).

Common Name	Scientific Name	Hardy	Campo	Dixon	Abundance
Three-toed Amphiuma	*Amphiuma tridactylum*	x		x	
Lesser Siren	*Siren intermedia*		x	x	
Gulf Coast Water Dog	*Necturus beyeri*	x			
Newt	*Notophthalmus viridescens*	x		x	
Spotted Salamander	*Ambystoma maculatum*	x		x	C
Marbled Salamander	*Ambystoma opacum*	x		x	
Mole Salamander	*Ambystoma talpoideum*	x	x	x	
Smallmouth Salamander	*Ambystoma texanum*	x		x	
Tiger Salamander	*Ambystoma tigrinum*	x		x	
Dusky Salamander	*Desmognathus auriculatus*	x		x	
Dwarf Salamander	*Eurycea quadridigitata*	x		x	
Slimy Salamander	*Plethodon glutinosus*	x			
Eastern Spadefoot	*Scaphiopus holbrooki*	x		x	
American Toad	*Bufo americanus*	x		x	A
Woodhouse's Toad	*Bufo woodhousei*	x		x	
Gulf Coast Toad	*Bufo valliceps*	x			
Eastern Narrowmouth Toad	*Gastrophryne carolinensis*	x		x	
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	x		x	
Northern Cricket Frog	*Acris crepitans*	x		x	
Cope's Gray Treefrog	*Hyla chrysoscelis*	x		x	
Green Treefrog	*Hyla cinerea*	x		x	
Squirrel Treefrog	*Hyla squirella*	x		x	
Spring Peeper	*Hyla crucifer*			x	
Strecker's Chorus Frog	*Pseudacris streckeri*	x			

Common Name	Scientific Name	Hardy	Campo	Dixon	Abundance
Northern Chorus Frog	*Pseudacris triseriata*	x		x	
Spotted Chorus Frog	*Pseudacris clarki*	x			
Bullfrog	*Rana catesbeiana*	x	x	x	C
Green Frog	*Rana clamitans*	x		x	
Pickerel Frog	*Rana palustris*	x		x	
Southern Leopard Frog	*Rana sphenocephala*			x	
Pig Frog	*Rana grylio*			x	

CLASS REPTILIA

Hardy (1994) of Louisiana State University at Shreveport is in the process of surveying 53 regional collections for reptile specimens. He lists 59 species which are known to exist in the area. Campo (1986) lists 10 species in his report. Using the range data from museum collections and a literature review, Dixon (1987) reported that there could be 53 species in Harrison or Marion Counties. Brantley (LHAAP 1993) has confirmed sightings of 16 reptile species on LHAAP. The abundances are based on his data, where A = abundant, C = common, and R = rare. Nomenclature follows that of Dixon (1987). Based on these sources, there could be 59 species at LHAAP.

Common Name	Scientific Name	Hardy	Campo	Dixon	Brantley	Abundance
Snapping Turtle	*Chelydra serpentina*	x		x	x	C
Alligator Snapping Turtle	*Macroclemys temmincki*	x	x	x	x	C
Yellow Mud Turtle	*Kinosternon flavescens*	x		x		
Eastern Mud Turtle	*Kinosternon subrubrum*	x		x		
Razorback Musk Turtle	*Sternotherus carinatus*	x		x		
Stinkpot	*Sternotherus odoratus*	x		x	x	C
Cooter	*Pseudomys floridana*	x				
Painted Turtle	*Chrysemys picta*	x		x		
Slider	*Trachemys scripta*	x		x		
River Cooter	*Pseudemys concinna*	x		x		
Chicken Turtle	*Deirochelys reticularia*	x		x		
Mississippi Map Turtle	*Graptemys kohni*	x		x		
False Map Turtle	*Graptemys pseudogeographica*	x		x		
Eastern Box Turtle	*Terrapene carolina*	x		x	x	A
Western Box Turtle	*Terrapene ornata*	x		x		
Smooth Softshell	*Trionyx muticus*	x		x	x	C
Spiny Softshell	*Trionyx spiniferus*	x		x		
Mediterranean Gecko	*Hemidactylus turcicus*	x				
Green Anole	*Anolis carolinensis*	x		x		
Eastern Fence Lizard	*Sceloporus undulatus*	x		x		
Texas Spiny Lizard	*Sceloporus olivaceus*	x				
Texas Horned Lizard	*Phrynosoma cornutum*		x			
Coal Skink	*Eumeces anthracinus*	x		x		
Five-lined Skink	*Eumeces fasciatus*	x		x		
Prairie Skink	*Eumeces septentrionalis*	x		x		

Common Name	Scientific Name	Hardy	Campo	Dixon	Brantley	Abundance
Broadhead Skink	*Eumeces laticeps*			x		
Ground Skink	*Scincella lateralis*	x		x		
Six-lined Racerunner	*Cnemidophorus sexineatus*			x		
Texas Spotted Whiptail	*Cnemidophorus gularis*			x	x	R
Slender Glass Lizard	*Ophisaurus attenuatus*	x		x	x	R
Scarlet Snake	*Cemophora coccinea*	x		x		
Racer	*Coluber constrictor*	x	x	x	x	C
Eastern Ringneck Snake	*Diadophis punctatus*	x		x		
Rat Snake	*Elaphe obsoleta*	x		x	x	C
Pine Snake (Bullsnake)	*Pituophis melanoleucus*		x		x	R
Mud Snake	*Farancia abacura*	x		x		
Eastern Hognose Snake	*Heterodon platyrhinos*	x		x	x	C
Prairie Kingsnake	*Lampropeltis calligaster*	x		x		
Common Kingsnake	*Lampropeltis getulus*	x		x	x	A
Milk Snake	*Lampropeltis triangulum*	x	x	x	x	C
Eastern Coachwhip	*Masticophis flagellum*	x	x	x	x	A
Green Water Snake	*Nerodia cyclopion*	x		x		
Plain-bellied Water Snake	*Nerodia erythrogaster*	x		x	x	C
Broad-banded Water Snake	*Nerodia fasciata*			x	x	C
Diamond-backed Water Snake	*Nerodia rhombifera*	x		x	x	C
Rough Green Snake	*Opheodrys aestivus*	x		x		
Gulf (Glossy) Crayfish Snake	*Regina rigida*	x		x		
Graham's Crayfish Snake	*Regina grahami*	x				
Brown Snake	*Storeria dekayi*	x		x		
Red-bellied Snake	*Storeria occipitomaculata*	x		x		
Flat-headed Snake	*Tantilla gracilis*	x		x		
Western Ribbon Snake	*Thamnophis proximus*	x		x	x	C
Rough Earth Snake	*Virginia striatula*	x		x		
Lined Snake	*Tropidoclonion lineatum*	x		x		
Coral Snake	*Micrurus fulvius*	x	x	x	x	C
Southern Copperhead	*Agkistrodon contortrix*	x	x	x	x	A
Cottonmouth	*Agkistrodon piscivorus*	x	x	x	x	A
Pygmy Rattlesnake	*Sistrurus miliarius*	x		x		
Timber Rattlesnake	*Crotalus horridus*	x			x	R
American Alligator	*Alligator mississippiensis*	x	x	x	x	R

CLASS AVES

Ingold (1994) of Louisiana State University at Shreveport has documented the avifauna of the Caddo Lake drainage system. His beginning point of reference is Oberholser (1974) who lists 226 species based on specimens and sightings. In addition, Ingold has added 32 more species for a total of 258 species. He has studied 23 bird collections and will eventually examine a total of 53 collections. He has also conducted literature searches of national, regional, and state scientific journals to look for additional species to add to the list.

Metzler (1994) of Longview, Texas, is in the process of preparing a field checklist of the birds of Caddo Lake, including Caddo Lake State Park and the Wildlife Management Area. She lists a total of 170 species along with their abundance and seasonal presence. Brantley (1995) has made sightings of 151 bird species on the property (LHAAP 1993). The abundance estimates in this table come from Brantley. Consideration of all of the above sources suggests that there could be 260 species that occupy LHAAP sometime during the year. Nomenclature follows that of Rappole and Blacklock (1994).

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Red-throated Loon	*Gavia stellata*	x			
Yellow-throated Loon	*Gavia adamsii*	x			
Pacific Loon	*Gavia pacifica*	x			
Common Loon	*Gavia immer*	x		x	R
Pied-billed Grebe	*Podilymbus podiceps*	x	x	x	C
Horned Grebe	*Podiceps auritus*	x	x	x	C
Eared Grebe	*Podiceps nigricollis*	x	x	x	C
Least Grebe	*Podiceps dominicus*			x	
Red-necked Grebe	*Podiceps grisegena*	x			
Western Grebe	*Aechmophorus occidentalis*	x			
American White Pelican	*Pelecanus erythrorhynchos*	x	x	x	C
Brown Pelican	*Pelecanus occidentalis*	x			
Double-crested Cormorant	*Phalacrocorax auritus*	x	x	x	C
Olivaceous Cormorant	*Phalacrocorax olivaceus*	x			
Anhinga	*Anhinga anhinga*	x	x		
American Bittern	*Botaurus lentiginosus*	x		x	
Least Bittern	*Ixobrychus exilis*	x			
Great Blue Heron	*Ardea herodias*	x	x	x	A
Great Egret	*Casmerodius albus*	x	x	x	A
Snowy Egret	*Egretta thula*	x	x	x	C
Reddish Egret	*Egretta rufescens*	x			
Little Blue Heron	*Egretta caerulea*	x	x	x	C
Tricolored Heron	*Egretta tricolor*	x	x	x	R
Cattle Egret	*Bubulcus ibis*	x	x	x	A
Green Heron	*Butorides virescens*	x	x	x	A
Black-crowned Night-Heron	*Nycticorax nycticorax*	x	x		R
Yellow-crowned Night-Heron	*Nyctanassa violacea*	x	x	x	R
White Ibis	*Eudocimus albus*	x	x		R
White-faced Ibis	*Plegadis chihi*	x			
Roseate Spoonbill	*Ajaia ajaja*	x			
Wood Stork	*Mycteria americana*	x	x	x	R
Black-bellied Whistling-duck	*Dendrocygna autumnalis*	x		x	R
Tundra Swan	*Cygnus columbianus*	x			
Mute Swan	*Cygnus olor*	x			
Greater White-fronted Goose	*Anser albifrons*	x	x		R
Snow Goose	*Chen caerulescens*	x		x	C
Ross' Goose	*Chen rossii*	x			

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Canada Goose	*Branta canadensis*	x	x	x	R
Wood Duck	*Aix sponsa*	x	x	x	C
Green-winged Teal	*Anas crecca*	x	x	x	R
American Black Duck	*Anas rubripes*	x		x	
Mallard	*Anas platyrhynchos*	x	x	x	C
Mottled Duck	*Anas fulvigula*	x			
Northern Pintail	*Anas acuta*	x	x	x	R
Blue-winged Teal	*Anas discors*	x	x	x	C
Cinnamon Teal	*Anas cyanoptera*	x			
Northern Shoveler	*Anas clypeata*	x	x	x	C
Gadwall	*Anas strepera*	x	x	x	C
American Wigeon	*Anas americana*	x	x	x	C
Canvasback	*Aythya valisineria*	x	x	x	R
Redhead	*Aythya americana*	x	x	x	C
Ring-necked Duck	*Aythya collaris*	x	x	x	R
Greater Scaup	*Aythya marila*	x			
Lesser Scaup	*Aythya affinis*	x	x	x	C
Oldsquaw	*Clangula hyemalis*	x		x	R
White-winged Scoter	*Melanitta fusca*	x			
Surf Scoter	*Melanitta perspicillata*	x			
Common Goldeneye	*Bucephala clangula*	x		x	
Bufflehead	*Bucephala albeola*	x	x	x	C
Hooded Merganser	*Lophodytes cucullatus*	x	x		R
Common Merganser	*Mergus merganser*	x		x	
Red-breasted merganser	*Mergus serrator*	x			
Ruddy Duck	*Oxyura jamaicensis*	x	x	x	R
Black Vulture	*Coragyps atratus*	x	x	x	C
Turkey Vulture	*Cathartes aura*	x	x	x	A
Osprey	*Pandion haliaetus*	x	x	x	R
American Swallow-tailed Kite	*Elanoides forficatus*	x			
White-tailed Kite	*Elanus leucurus*	x			
Mississippi Kite	*Ictinia mississippiensis*	x	x	x	C
Northern Harrier	*Circus cyaneus*	x	x		R
Sharp-shinned Hawk	*Accipiter striatus*	x	x	x	C
Cooper's Hawk	*Accipiter cooperii*	x	x	x	C
Red-shouldered Hawk	*Buteo lineatus*	x	x	x	C
Broad-winged Hawk	*Buteo platypterus*	x	x		R
Swainson's Hawk	*Buteo swainsoni*	x			
Red-tailed Hawk	*Buteo jamaicensis*	x	x	x	C
Ferruginous Hawk	*Buteo regalis*	x			
Rough-legged Hawk	*Buteo lagopus*	x		x	
Golden Eagle	*Aquila chrysaetos*	x			
Bald Eagle	*Haliaeetus leucocephalus*	x	x	x	R
Marsh Hawk	*Circus cyaneus*			x	
American Kestrel	*Falco sparverius*	x	x	x	C
Merlin	*Falco columbarius*	x			
Peregrine Falcon	*Falco peregrinus*	x			
Greater Prairie Chicken	*Tympanuchus cupido*	x			
Wild Turkey	*Meleagris gallopavo*	x	x	x	R
Northern Bobwhite	*Colinus virginianus*	x	x	x	C
Yellow Rail	*Coturnicops noveboracensis*	x			
Black Rail	*Laterallus jamaicensis*	x			
King Rail	*Rallus elegans*	x	x	x	R

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Virginia Rail	*Rallus limicola*	x			
Sora	*Porzana carolina*	x		x	R
Purple Gallinule	*Porphyrula martinica*	x	x	x	R
Common Moorhen	*Gallinula chloropus*	x	x	x	R
American Coot	*Fulica americana*	x	x	x	A
Sandhill Crane	*Grus canadensis*	x			
Black-bellied Plover	*Pluvialis squatarola*	x	x		R
American Golden-Plover	*Charadrius dominica*	x		x	R
Semipalmated Plover	*Charadrius semipalmatus*	x			
Piping Plover	*Charadrius melodus*	x			
Killdeer	*Charadrius vociferus*	x	x	x	C
Black-necked Stilt	*Himantopus mexicanus*	x			
American Avocet	*Recurvirostra americana*	x			
Greater Yellowlegs	*Tringa melanoleuca*	x	x		R
Lesser Yellowlegs	*Tringa flavipes*	x		x	
Solitary Sandpiper	*Tringa solitaria*	x	x		R
Willet	*Catoptrophorus semipalmatus*	x			
Spotted Sandpiper	*Actitis macularia*	x	x		R
Upland Sandpiper	*Bartramia longicauda*	x			
Long-billed Curlew	*Numenius americanus*	x			
Hudsonian Godwit	*Limosa haemastica*	x			
Whimbrel	*Numenius phaeopus*	x			
Ruddy Turnstone	*Arenaria interpres*	x			
Sanderling	*Calidris alba*	x			
Semipalmated Sandpiper	*Calidris pusilla*	x	x		R
Western Sandpiper	*Calidris mauri*	x	x		R
Least Sandpiper	*Calidris minutilla*	x	x		R
White-rumped Sandpiper	*Calidris fuscicollis*	x			
Baird's Sandpiper	*Calidris bairdii*	x			
Pectoral Sandpiper	*Calidris melanotos*	x			
Dunlin	*Calidris alpina*	x			
Stilt Sandpiper	*Calidris himantopus*	x			
Buff-breasted Sandpiper	*Tryngites subruficollis*	x			
Short-billed Dowitcher	*Limnodromus griseus*	x			
Long-billed Dowitcher	*Limnodromus scolopaceus*	x			
Common Snipe	*Gallinago gallinago*	x	x	x	R
American Woodcock	*Scolopax minor*	x	x	x	C
Wilson's Phalarope	*Phalaropus tricolor*	x			
Red-necked Phalarope	*Lobipes lobatus*	x			
Laughing Gull	*Larus atricilla*	x			
Franklin's Gull	*Larus pipixcan*	x			
Bonaparte's Gull	*Larus philadelphia*	x	x		R
Ring-billed Gull	*Larus delawarensis*	x	x		C
Herring Gull	*Larus argentatus*	x			
Great Black-backed Gull	*Larus marinus*	x			
Black-legged Kittiwake	*Rissa tridactyla*	x			
Glaucous Gull	*Larus hyperboreus*	x			
Caspian Tern	*Sterna caspia*	x			
Sooty Tern	*Sterna fuscata*	x			
Common Tern	*Sterna hirundo*	x			
Forster's Tern	*Sterna forsteri*	x	x		R
Least Tern	*Sterna antillarum*	x			
Black Tern	*Chlidonias niger*	x			
Rock Dove	*Columba livia*	x	x	x	C

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Band-tailed Pigeon	*Columba fasciata*	x			
Ringed Turtle-Dove	*Streptopelia risoria*	x			
White-winged Dove	*Zenaida asiatica*	x			
Mourning Dove	*Zenaida macroura*	x	x	x	A
Inca Dove	*Columbina inca*	x	x	x	R
Common Ground-Dove	*Columbina passerina*	x	x		R
Carolina Parakeet	*Canuropsis carolinensis*	x			
Black-billed Cuckoo	*Coccyzus erythropthalmus*	x	x		R
Yellow-billed Cuckoo	*Coccyzus americanus*	x	x	x	A
Greater Roadrunner	*Geococcyx californianus*	x	x	x	A
Groove-billed Ani	*Crotophaga sulcirostris*	x			
Barn Owl	*Tyto alba*	x		x	
Eastern Screech Owl	*Otus asio*	x	x	x	C
Great Horned Owl	*Bubo virginianus*	x	x		R
Snowy Owl	*Nyctea scandica*	x			
Burrowing Owl	*Athene cunicularia*	x			
Barred Owl	*Strix varia*	x	x	x	A
Long-eared Owl	*Asio otus*	x			
Short-eared Owl	*Asio flammeus*	x			
Common Nighthawk	*Chordeiles minor*	x		x	C
Chuck-will's-widow	*Caprimulgus carolinensis*	x	x	x	C
Whip-poor-will	*Caprimulgus vociferous*	x	x		C
Chimney Swift	*Chaetura pelagica*	x	x	x	C
Ruby-throated Hummingbird	*Archilochus colubris*	x	x	x	C
Broad-tailed Hummingbird	*Selasphorus platycercus*	x			
Rufous Hummingbird	*Selasphorus rufus*	x			
Belted Kingfisher	*Ceryle alcyon*	x	x	x	A
Red-headed Woodpecker	*Melanerpes erythrocephalus*	x	x	x	C
Red-bellied Woodpecker	*Melanerpes carolinus*	x	x	x	A
Yellow-bellied Sapsucker	*Sphyrapicus varius*	x	x	x	C
Downy Woodpecker	*Picoides pubescens*	x	x	x	A
Hairy Woodpecker	*Picoides villosus*	x	x	x	C
Red-cockaded Woodpecker	*Picoides borealis*	x		x	
Northern Flicker	*Colaptes auratus*	x	x	x	A
Pileated Woodpecker	*Dryocopus pileatus*	x	x	x	A
Ivory-billed Woodpecker	*Campephilus principalis*	x			
Olive-sided Flycatcher	*Contopus borealis*	x	x		R
Eastern Wood-Pewee	*Contopus virens*	x	x	x	C
Yellow-bellied Flycatcher	*Empidonax flaviventris*	x	x		R
Acadian Flycatcher	*Empidonax virescens*	x	x		C
Willow (Trail's) Flycatcher	*Empidonax traillii*	x			
Least Flycatcher	*Empidonax minimus*	x	x		R
Eastern Phoebe	*Sayornis phoebe*	x	x	x	R
Say's Phoebe	*Sayornis saya*	x			
Vermillion Flycatcher	*Pyrocephalus rubinus*	x			
Ash-throated Flycatcher	*Myiarchus cinerascens*	x			
Great Crested Flycatcher	*Myiarchus crinitus*	x	x		C
Western Kingbird	*Tyrannus verticalis*	x			
Eastern Kingbird	*Tyrannus tyrannus*	x	x	x	A
Scissor-tailed Flycatcher	*Tyrannus forficatus*	x	x	x	A
Horned Lark	*Eremophila alpestris*	x			
Purple Martin	*Progne subis*	x	x	x	A

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Tree Swallow	*Tachycineta bicolor*	x			
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	x	x		R
Bank Swallow	*Riparia riparia*	x		x	
Cliff Swallow	*Hirundo pyrrhonota*	x			
Barn Swallow	*Hirundo rustica*	x	x		A
Blue Jay	*Cyanocitta cristata*	x	x	x	A
American Crow	*Corvus brachyrhynchos*	x	x	x	A
Fish Crow	*Corvus ossifragus*	x	x	x	A
Black-capped Chickadee	*Parus atricapillus*	x			
Carolina Chickadee	*Parus carolinensis*	x	x	x	A
Tufted Titmouse	*Parus bicolor*	x	x	x	A
Red-breasted Nuthatch	*Sitta canadensis*	x	x	x	R
White-breasted Nuthatch	*Sitta carolinensis*	x	x		C
Brown-headed Nuthatch	*Sitta pusilla*	x	x	x	R
Brown Creeper	*Certhia americana*	x	x	x	R
Carolina Wren	*Thryothorus ludovicianus*	x	x	x	A
Bewick's Wren	*Thryomanes bewickii*	x			
House Wren	*Troglodytus aedon*	x	x		R
Winter Wren	*Troglodytes troglodytes*	x	x		R
Sedge Wren	*Cistothorus platensis*	x		x	
Marsh Wren	*Cistothorus palustris*	x		x	
Rock Wren	*Salpinctes obsoletus*	x			
Golden-crowned Kinglet	*Regulus satrapa*	x	x	x	R
Ruby-crowned Kinglet	*Regulus calendula*	x	x	x	C
Blue-gray Gnatcatcher	*Polioptila caerulea*	x	x	x	C
Eastern Bluebird	*Sialia sialis*	x	x	x	C
Veery	*Catharus fuscescens*	x		x	A
Gray-cheeked Thrush	*Catharus minimus*	x			
Swainson's Thrush	*Catharus ustulatus*	x	x	x	C
Hermit Thrush	*Catharus guttatus*	x	x	x	C
Wood Thrush	*Hylocichla mustelina*	x	x	x	C
American Robin	*Turdus migratorius*	x	x	x	A
Gray Catbird	*Dumetella carolinensis*	x	x	x	C
Northern Mockingbird	*Mimus polyglottos*	x	x	x	A
Brown Thrasher	*Toxostoma rufum*	x	x	x	A
American Pipit	*Anthus rubescens*	x			
Sprague's Pipit	*Anthus spragueii*	x			
Cedar Waxwing	*Bombycilla cedrorum*	x	x	x	C
Loggerhead Shrike	*Lanius ludovicianus*	x	x	x	C
European Starling	*Sturnus vulgaris*	x	x	x	R
White-eyed Vireo	*Vireo griseus*	x	x	x	A
Bell's Vireo	*Vireo bellii*	x			
Solitary Vireo	*Vireo solitarius*	x	x		R
Yellow-throated Vireo	*Vireo flavifrons*	x	x		R
Philadelphia Vireo	*Vireo philadelphicus*	x			
Warbling Vireo	*Vireo gilvus*	x	x		R
Red-eyed Vireo	*Vireo olivaceus*	x	x		A
Blue-winged Warbler	*Vermivora pinus*	x			
Golden-winged Warbler	*Vermivora chrysoptera*	x			
Tennessee Warbler	*Vermivora peregrina*	x	x		R
Orange-crowned Warbler	*Vermicora celata*	x	x		R
Nashville Warbler	*Vermicora ruficapilla*	x			

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Northern Parula	*Parula americana*	x		x	A
Yellow Warbler	*Dendroica petechia*	x		x	R
Chestnut-sided Warbler	*Dendroica pensylvanica*	x			
Magnolia Warbler	*Dendroica magnolia*	x	x		R
Yellow-rumped Warbler	*Dendroica coronata*	x	x	x	R
Black-throated Blue Warbler	*Dendroica caerulescens*	x			
Black-throated Green Warbler	*Dendroica virens*	x	x		R
Blackburnian Warbler	*Dendroica fusca*	x			
Yellow-throated Warbler	*Dendroica dominica*	x	x	x	C
Pine Warbler	*Dendroica pinus*	x	x	x	C
Prairie Warbler	*Dendroica discolor*	x			
Palm Warbler	*Dendroica palmarum*	x			
Bay-breasted Warbler	*Dendroica castanea*	x			
Blackpoll Warbler	*Dendroica striata*	x	x		R
Cerulean Warbler	*Dendroica cerulea*	x		x	
Black-and-white Warbler	*Mniotilta varia*	x	x	x	C
American Redstart	*Setophaga ruticilla*	x		x	
Prothonotary Warbler	*Protonotaria citrea*	x		x	
Worm-eating Warbler	*Helmitheros vermivorus*	x	x		R
Swainson's Warbler	*Limnothlypis swainsonii*	x	x		R
Ovenbird	*Seiurus aurocapillus*	x			
Northern Waterthrush	*Seiurus noveboracensis*	x			
Louisiana Waterthrush	*Seiurus motacilla*	x	x	x	R
Kentucky Warbler	*Oporornis formosus*	x	x		R
Connecticut Warbler	*Oporornis agilis*	x			
Mourning Warbler	*Oporornis philadelphia*	x			
Common Yellowthroat	*Geothlypis trichas*	x	x	x	R
Hooded Warbler	*Wilsonia citrina*	x			
Wilson's Warbler	*Wilsonia pusilla*	x			
Canada Warbler	*Wilsonia canadensis*	x			
Yellow-breasted Chat	*Icteria virens*	x	x	x	A
Summer Tanager	*Piranga rubra*	x	x	x	A
Scarlet Tanager	*Piranga olivacea*	x		x	
Western Tanager	*Piranga ludoviciana*	x			
Northern Cardinal	*Cardinalis cardinalis*	x	x	x	A
Rose-breasted Grosbeak	*Pheucticus ludovicinaus*	x		x	R
Black-headed Grosbeak	*Pheucticus melanocephalus*	x			
Blue Grosbeak	*Guiraca caerulea*	x	x	x	A
Indigo Bunting	*Passerina cyanea*	x	x	x	A
Lazuli Bunting	*Passerina amoena*	x			
Painted Bunting	*Passerina ciris*	x	x	x	A
Dickcissel	*Spiza americana*	x			
Rufous-sided Towhee	*Pipilo erythrophthalmus*	x		x	A
Green-tailed Towhee	*Pipilo chlorurus*	x			
Lark Bunting	*Calamospiza melanocorys*	x			
Bachman's Sparrow	*Aimophila aestivalis*	x		x	C
American Tree Sparrow	*Spizella arborea*	x			
Chipping Sparrow	*Spizella passerina*	x	x	x	C
Clay-colored Sparrow	*Spizella pallida*	x		x	R
Field Sparrow	*Spizella pusilla*	x	x	x	C
Vesper Sparrow	*Pooecetes gramineus*	x		x	
Lark Sparrow	*Chondestes grammacus*	x			

Common Name	Scientific Name	Ingold	Metzler	Brantley	Abundance
Black-throated Sparrow	*Amphispiza bilineata*	x			
Savannah Sparrow	*Passerculus sandwichensis*	x			
Grasshopper Sparrow	*Ammodramus savannarum*	x			
Henslow's Sparrow	*Ammodramus henslowii*	x			
LeConte's Sparrow	*Ammodramus leconteii*	x			
Sharp-tailed Sparrow	*Ammodramus caudacutus*	x			
Fox Sparrow	*Passerella iliaca*	x		x	R
Song Sparrow	*Melospiza melodia*	x	x	x	R
Lincoln's Sparrow	*Melospiza lincolnii*	x	x		R
Swamp Sparrow	*Melospiza georgiana*	x	x	x	R
White-throated Sparrow	*Zonotrichia albicollis*	x	x	x	A
Golden-crowned Sparrow	*Zonotrichia atricapilla*	x			
White-crowned Sparrow	*Zonotrichia leucophrys*	x	x	x	A
Harris' Sparrow	*Zonotrichia querula*	x			
Dark-eyed Junco	*Junco hyemalis*	x	x	x	C
Lapland Longspur	*Calcarius lapponicus*	x			
Bobolink	*Dolichonyx oryzivorus*	x			
Red-winged Blackbird	*Agelaius phoeniceus*	x	x	x	A
Eastern Meadowlark	*Sturnella magna*	x	x	x	A
Western Meadowlark	*Sturnella neglecta*	x		x	
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	x			
Rusty Blackbird	*Euphagus carolinus*	x		x	A
Brewer's Blackbird	*Euphagus cyanocephalus*	x		x	A
Great-tailed Grackle	*Quiscalus mexicanus*	x			
Common Grackle	*Quiscalus quiscula*	x	x	x	A
Brown-headed Cowbird	*Molothrus ater*	x	x	x	A
Orchard Oriole	*Icterus spurius*	x	x	x	A
Northern Oriole	*Icterus galbula*	x	x		R
Purple Finch	*Carpodacus purpureus*	x		x	
House Finch	*Carpodacus mexicanus*	x	x		R
Red Crossbill	*Loxia curvirostra*	x			
Pine Siskin	*Carduelis pinus*	x		x	A
American Goldfinch	*Carduelis tristis*	x	x	x	A
Evening Grosbeak	*Coccothraustes verpertinus*	x			
House Sparrow	*Passer domesticus*	x	x	x	A

CLASS MAMMALIA

Davis (1974) reported 156 native mammalian species in Texas with six additional species introduced: the house mouse, roof rat, Norway rat, nutria, axis deer, and Barbary sheep. Based on his distribution records there are 51 species that are probable in the LHAAP area. Campo (1986), a wildlife biologist for the TPWD, has compiled a list of 26 species of mammals that are known to inhabit the Cypress Bayou Basin. Brantley (LHAAP 1993) has confirmed sightings of 16 species on LHAAP. The abundances are based on his data, where A = abundant, C = common, and R = rare. Based on these these sources, a total of 44 mammalian species could exist at LHAAP. Nomenclature follows that of Davis (1994).

Common Name	Scientific Name	Davis	Campo	Brantley	Abundance
Virginia Opossum	*Didelphius virginiana*	x	x	x	A
Eastern Mole	*Scalopus aquaticus*	x		x	A
Southern Short-tailed Shrew	*Blarina carolinensis*	x		x	R
Least Shrew	*Cryptotis parva*	x			
Southeastern Myotis Bat	*Myotis austroriparius*	x	x		
Silver-haired Bat	*Lasionycteris noctivagans*	x			
Eastern Pipistrelle	*Pipistrellus subflavus*	x			
Big Brown Bat	*Eptesicus fuscus*	x			
Eastern Red Bat	*Lasiurus borealis*	x			
Seminole Bat	*Lasiurus seminolus*	x			
Evening Bat	*Nycticeius humeralis*	x			
Rafinesque's Big-eared Bat	*Plecotus rafinesquii*	x	x		
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	x			
Raccoon	*Procyon lotor*	x	x	x	A
Ringtail	*Bassariscus astutus*	x			
Long-tailed Weasel	*Mustela frenata*	x	x		
Mink	*Mustela vison*	x	x	x	A
River Otter	*Lutra canadensis*	x		x	C
Eastern Spotted Skunk	*Spilogale putorius*	x	x		
Striped Skunk	*Mephitis mephitis*	x	x	x	A
Red Fox	*Vulpes vulpes*	x		x	C
Common Gray Fox	*Urocyon cinereoargenteus*	x	x	x	A
Coyote	*Canis latrans*	x	x	x	A
Bobcat	*Lynx rufus*	x	x	x	C
Eastern Gray Squirrel	*Sciurus carolinensis*	x	x	x	A
Eastern Fox Squirrel	*Sciurus niger*	x	x	x	A
Eastern Flying Squirrel	*Glaucomys volans*	x	x	x	A
Baird's Pocket Gopher	*Geomys breviceps*	x	x	x	A
Hispid Pocket Mouse	*Chaetodipus hispidus*	x	x	x	C
American Beaver	*Castor canadensis*	x	x	x	A
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	x	x	x	C
White-footed Mouse	*Peromyscus leucopus*	x	x	x	C
Cotton Mouse	*Peromyscus gossypinus*	x	x	x	C
Golden Mouse	*Ochrotomys nuttalli*	x			
Marsh Rice Rat	*Oryzomys palustris*	x		x	C
Eastern Harvest Mouse	*Reithrodontomys humulis*	x			
Deer Mouse	*Peromyscus maniculatus*	x			
Northern Pygmy Mouse	*Baiomys taylori*	x			
Hispid Cotton Rat	*Sigmodon hispidus*	x	x	x	C
Eastern Woodrat	*Neotoma floridana*	x		x	C
Woodland Vole	*Microtus pinetorum*	x			
Common Muskrat	*Ondatra zibethicus*	x	x	x	R
House Mouse	*Mus musculus*	x		x	
Roof Rat	*Rattus rattus*	x		x	C
Norway Rat	*Rattus norvegicus*	x		x	C
Nutria	*Myocastor coypus*	x	x	x	C
Eastern Cottontail	*Sylvilagus floridanus*	x	x	x	C
Black-tailed Jackrabbit	*Lepus californicus*	x			
Swamp Rabbit	*Sylvilagus aquaticus*	x	x	x	C
White-tailed Deer	*Odocoileus virginianus*	x	x	x	C
Nine-banded Armadillo	*Dasypus novemcinctus*	x	x	x	C

In addition to these species, there have been five known sightings of a large cat on the property over the last few years. The animal has been described as a black cougar, puma, timber lion, and black panther by different individuals. Descriptive information provided by several individuals leds to the conclusion that this is most probably a cougar. However, according to Davis (1974) the cougar (*Felis concolor)* has not been reported from the northeast region of Texas. The sightings are as follows:

(1) Mr. Robert Layman, a security guard at LHAAP, saw a black puma or cougar in the summer of 1993 on a loading dock on 25th street at about 2:30 a.m.(S32)

(2) Tom Brantley saw a tan puma/cougar on Avenue P at the southeast end of the magazine area about 80 yards from gate 10. The size of the cat was estimated to be 2 1/2 feet at the shoulder and seven feet from nose to tail. (S33)

(3) Mr. Layman saw a large black cat at plant site 27A-29 in the summer of 1993. (S34)

(4) A plant expeditor saw a "timber lion" crossing 51st street (S35)

(5) Two electricians saw a black panther near the pistol range at Harrison Bayou chasing a deer across the road.during the summer of 1993. (S36)

TABLE 1.
SUMMARY OF VERTEBRATE SPECIES AT LHAAP

VERTEBRATE CLASS	NUMBER OF SPECIES AT LHAAP	NUMBER OF SPECIES IN TEXAS	%
Agnatha & Osteichthyes	71	247	29
Amphibia	31	63	49
Reptilia	59	141	42
Aves	260	622	42
Mammalia	51	181	28
TOTAL	**472**	**1254**	**38**

TASK 2
ENDANGERED AND THREATENED SPECIES

A search of the literature resulted in the identification of 21 different animal species that could possibly occur on or near LHAAP that are on the federal or state endangered or threatened species lists. Three of the species are listed on both the state and federal lists, thus making a total of 24 species listings. Several other species having been identified as possible candidates for these lists. The lists were acquired from a report by Tom Cloud (1993) of the U.S. Fish and Wildlife Service and from the Endangered Resources Branch of the Texas Parks and Wildlife Department (1993). The lists were originally compiled by Tom Hayes of the Texas Nature Conservancy. Information about the life history and habitat requirement of the species was obtained from various agency personnel and literature sources as indicated. This section provides a brief discussion of the sighting of these species at LHAAP. More detailed field notes for these species are provided in Appendix 1.

FEDERAL ENDANGERED SPECIES

Bald Eagle (*Heliaeetus leucocephalus*)
The bald eagle is on both the federal and state endangered species lists. It is an uncommon visitor to the Caddo Lake area. The bald eagle over-winters (October - March) here and migrates to the north in the spring (Peterson 1963; Rappole and Blacklock 1994). It breeds along the rivers and reservoirs of east Texas. Bald eagles prefer habitats with lots of water and large trees for roosting and resting sites. Its food consists of fish, waterfowl, rabbits, and carrion.

There has been one unconfirmed sighting by oil field workers of bald eagles nesting on top of old oil platforms in the James Bayou area of Caddo Lake. There have been three confirmed sightings by Brantley (1995) at LHAAP:

(1) in the fall at Starr Ranch.
(2) in the winter of 1993 at Goose Prairie near the Starr Ranch boat ramp; the eagle was sighted perched in a cypress tree in the lake; site number S21.
(3) in the winter of 1993 an adult eagle was sighted flying over the maintenance parking lot; site number S22.

Red-cockaded Woodpecker (*Picoides borealis*)
The red-cockaded woodpecker is also on both federal and state endangered species lists. It is a non-migratory, local resident along the eastern edge of the state (Peterson 1963). Its major habitat is highly specific: open pine forests which have 70 year old pine trees (especially longleaf and loblolly) with very little undergrowth (Rappole and Blacklock 1994). Bent (1992) states that it is not found in cypress swamps and that it nests 25 to 50 feet off the ground in living, mature pine trees that have a dead center. Its food consists of wood-boring insect larvae.

This woodpecker has been sighted at LHAAP in mature pine stands and in mature mixed stands by Brantley (1995).

Wood Stork (*Mycteria americana*)
The wood stork is found as a common summer (July - September) resident along the Texas coast but is rare at large inland lakes. Pulich (1988) states that most sightings in the northern counties occur during late August and September. Although it may have bred in Texas at one time, present populations are composed of postbreeding transients, apparently from southern Mexico (Rappole and Blacklock 1994). Its habitat consists of swamps, marshes, and ponds. Frogs, crustaceans, lizards, insects, and rodents compose its diet (Peterson 1963).

There have been two confirmed sightings of wood storks by Brantley (1995) on LHAAP:
(1) in late September, 1993 at Duck Pond on Starr Ranch; site number S18.
(2) in the early fall, 1987 7 storks were observed flying over Starr Ranch; site number S19.

FEDERAL THREATENED SPECIES

American Alligator (*Alligator mississippiensis*)
The American alligator ranges throughout the southern United States from North Carolina to Texas (Blair et al. 1968). Once very common in the South, particularly in Florida, the alligator was hunted for many years for its valuable hide. The alligator is now commonly found in many secluded swamps and bayous (Ditmars 1936). Food consists of fish, mammals and birds. Younger alligators will feed on frogs, tadpoles, and insects. Brantley (1995) stated that alligators have been released at LHAAP for the purpose of controlling beaver populations. The alligator has been seen rarely on LHAAP by Brantley (1995).

Piping Plover (*Charadrius melodus*)
The piping plover is an uncommon winter resident along the Texas coast (Rappole and Blacklock 1994). It migrates through east Texas during February through March and again in the fall, August through November. It breeds in southern Canada and the northern United States. In Texas its habitats are usually sea beaches and flats. Food consists of insects, crustaceans, and worms.

Arctic Peregrine Falcon (*Falco peregrinus tundrius*)
The peregrine falcon is a rare to casual transient during spring (March - May) and fall (September - October) migrations in east Texas (Rappole and Blacklock 1994). It is a rare winter resident along the eastern coast of Texas. Its habitat is open country very close to a body of water. It feeds on birds, rodents, and insects. It needs tall cliffs (about 50 meters) for resting and perching (Johnsgard 1990).

STATE ENDANGERED SPECIES

Paddlefish (*Polydon spathula*)
The paddlefish was formerly abundant in the larger streams of the United States but now it is limited to the Great Lakes, rivers in Missouri, and tributaries of the Mississippi River (Blair et al. 1968). In Texas this species once occurred in every major river from the Trinity Basin eastward. By the 1950s, its numbers and range had been substantially reduced. A paddlefish restoration project has been initiated by the TPWD, including in the Cypress Bayou Basin. It is a filter feeder using its gills

to strain crustaceans and other small organisms out of the water. It spawns in the spring over gravel beds in swiftly flowing water (Eddy 1969). Brantley (1995) reported that it is often caught in Caddo Lake.

Louisiana Pine Snake (*Pituophis melanoleucus ruthveni*)
There are 11 subspecies of the pine snake in the United States. The species ranges from the eastern United States to Texas and the northern states to the Pacific Coast (Blair et al. 1968). This subspecies is found mostly in Louisiana and extreme east Texas. Its habitat is mostly sandy soils in longleaf pine woods (Conant 1975).

Pine snakes have been seen rarely by Brantley (1995) at LHAAP.

Bald Eagle (*Haliaeetus leucocephalus*)
See above.

Red-cockaded Woodpecker (*Picoides borealis*)
See above.

Louisiana Black Bear (*Ursus americanus luteolus*)
The black bear once ranged over most of the wooded areas of the contiguous United States but is now thought to be found only in southern Arkansas and western Louisiana (Walker 1964). There are sporadic unconfirmed reports by citizens, the TPWD, and others of the black bear occasionally appearing in the Caddo Lake area. It is known to be solitary except during the breeding season. It hibernates during the winter and during the rest of the year roams over an extensive home range. Its food consists of ants, grasshoppers, grasses, acorns, fruit, fish, and small mammals (Walker 1964).

STATE THREATENED SPECIES

Blackside Darter (*Percina maculata*)
The range of the blackside darter extends from southern Canada to northeastern Texas in the Red River basin (Blair et al. 1968, Hubbs et al. 1991). The species spawns in the spring. It is mostly piscivorous but will also feed on crustaceans and insects (Eddy 1969).

Bluehead Shiner (*Notropis hubbsi*)
According to Hubbs et al. (1991) the bluehead shiner only inhabits Caddo Lake and sporadically in Cypress swamps in Arkansas and Louisiana.

Creek Chubsucker (*Erimyzon oblongus*)
The range of the creek chubsucker is from southern Canada and northern United States to the southeastern United States and the Mississippi River system (Blair et al. 1968). In Texas it has been reported in eastern Texas streams from the Red River southward to the San Jacinto drainage

(Hubbs et al. 1991). It is considered to be an omnivore, feeding on various animal and plant matter at the bottom of streams. Spawning occurs in the spring in small tributaries with the eggs being scattered at random and developing without parental care (Eddy 1969).

Blue Sucker (*Cycleptus elongatus*)
The blue sucker is found in large streams and artificial impoundments from the Mississippi River to the Rio Grande (Blair et al. 1968). It is an omnivore on a variety of matter at the bottom of streams. It spawns in the spring in small tributaries (Eddy 1969).

Texas Horned Lizard (*Phrynosoma cornutum*)
The range of the horned lizard extends from Missouri to Colorado and south to Arizona and Texas (Blair et al. 1968). The species prefers a flat, open terrain with sparse plant cover on sandy or loamy soils. Its food consists of spiders, sowbugs, and insects, especially ants. (Conant 1975).

Alligator Snapping Turtle (*Macroclemys temminckii*)
The alligator snapping turtle is the largest freshwater turtle of the United States with maximum weight exceeding 300 pounds. Its range is from Florida to Texas and north to Illinois and Ohio (Blair et al. 1968). Its diet primarily consists of fish.

Brantley (1995) reported that he has witnessed this species commonly, especially during egg laying season as documented in the sightings on LHAAP property. There have been several confirmed sightings by others as well. The sightings include the following:

(1) in July, 1991 an employee named Ken Shackelford at LHAAP, saw a turtle in the virgin timber area of Harrison Bayou; site number S1.
(2) Brantley saw turtles along the banks of Harrison Bayou at the Harrison Bayou Bridge; site numbers S2 and S3.
(3) Brantley saw turtles at the Karnack Avenue bridge over Goose Prairie Creek; site number S4.
(4) from 1980-1990 Brantley saw turtles during the late spring and summer at a ditch along Avenue P; site number S5.
(5) in 1993 Brantley also saw turtles at a ditch along Avenue P; site number S6.
(6) from 1975-1983, Brantley saw turtles at the same ditch along Avenue P; site number S7.
(7) from 1985-1990 during the late spring Brantley saw turtles on a slope leading to Harrison Bayou outside the static test area; site number S8.
(8) in the spring of 1987 Truit Hammonds caught and killed an 18 inch female turtle with eggs; site number S9.
(9) during the spring from 1974-1978, fishermen reported seeing turtles at Starr Ranch; site number S10.
(10) during 1990 or 1991 Brantley and other employees saw turtles at a small pool in the mill house area; site number S11.
(11) in 1993 Brantley saw turtles at Bridge A24; site number S38.

Canebrake Rattlesnake (*Crotalus horridus atricaudatus*)
There are two subspecies of canebrake rattlesnakes found throughout the southeastern United States (Blair et al. 1968). Cane thickets and swamps are its main type of habitat. Its food consists of rodents, birds, frogs, and lizards (Conant 1975).

There has been one sighting of a 4 1/2 foot canebrake rattlesnake by Brantley (1995) on a logging road near Karnack Avenue; site number S31.

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Northern Scarlet Snake (*Cemophora coccinea copei*)
There are three subspecies of the scarlet snake found from New Jersey south along the Atlantic Coast to Florida and west to Texas and Oklahoma. It prefers habitats with sandy or loamy soils for burrowing or in logs. It kills small rodents, snakes, and lizards by constriction (Conant 1975).

White-faced Ibis (*Plegadis chihi*)
The white-faced ibis is a common transient (March - May and August - October) along the Texas coastal plain and a rare transient through the eastern half of Texas. It breeds along the south Texas coast through Mexico and into Central and South America. It prefers a marsh, swamp, lake, or pond habitat where it feeds on frogs, crustaceans, and insects (Peterson 1963).

Piping Plover (*Charadrius melodus*)
See above.

American Swallow-tailed Kite (*Elanoides forficatus*)
Once breeding over the eastern United States, the American swallow-tailed kite is now considered to be rare and found only in Louisiana, South Carolina, and Georgia (Rappole and Blacklock 1994). There is evidence that it once nested in north-central Texas before 1900 (Pulich 1988). It only visits east Texas rarely during migration periods (March - May) to South America. Its habitat is along creeks, rivers, and swamps, especially in wooded areas. Its food consists of small mammals, birds, reptiles, and insects (Peterson 1963).

Eastern Big-eared Bat (*Plecotus rafinesquei*)
This bat is found in the southeastern United States north to Ohio and south to southeastern Oklahoma (Blair et al. 1968). It prefers forest areas devoid of caves where it inhabits old buildings, tunnels, and hollow trees (Walker 1964, Davis 1974). Its food consists of insects, especially moths. Walker (1964) states that the species undergoes no extensive migrations and that it hibernates during the winter. However, Davis (1974) suggests that it does not hibernate in the milder climates of Texas. It has been reported from Marion County as well as several other northeast Texas counties.

River Otter (*Lutra canadensis*)
The range of the river otter extends throughout Alaska and Canada south through much of the United States except in the arid southwestern states (Blair et al. 1968). Its food consists of fish (nongame mostly), crayfish, frogs, salamanders, insects, worms, turtles, clams, and mussels (Walker 1964).

There have been several sightings of river otters by Brantley (1995) and a trapper named Dunnier
(1) in 1993 in Kamack Creek; site number S26A.
(2) at the east overflow channel bridge on Harrison Bayou Road; site number S28.
(3) on Starr Ranch; site number S25.

Sightings of endangered and threatened species in the LHAAP area are summarized in Table 2. 020163

TABLE 2.
FEDERAL AND STATE THREATENED AND ENDANGERED SPECIES , LHAAP

	Federal Endangered	Federal Threatened	State Endangered	State Threatened	Totals
Possible Species	3	3	5	13	24
Sightings	3	1	4	3	11

CATEGORY 2 CANDIDATE SPECIES

The following 14 species are not on the federal endangered or threatened lists but are being currently studied as potential candidates for listing. These are termed category 2 candidate species which means that they are under current review for possible listing. Information indicates that proposing to list as endangered or threatened is possibly appropriate, but substantial data on biological vulnerability and threats are not currently known to support the immediate preparation or rules. Further biological research and field study will be necessary to ascertain the status and/or taxonomic validity of the taxa. This list is from Cloud (1993), except for the aster which is from Cloud and Watson (1991).

Common Name	Scientific Name
Aster	*Aster puniceus elliotti* var. scabricaulis [Wood Co., Texas]
Golden Wave Tickseed	*Coreopsis intermedia*
Barberry-leaved Hawthorn	*Crateagus berberifolia*
Southern Lady's Slipper Orchid	*Cypripedium kentuckiense*
Neches River Rosemallow	*Hibiscus dasycalyx*
Texas Trillium	*Trillium pusillum* var. texanum
Blue Sucker	*Cycleptus elongatus*
Alligator Snapping Turtle	*Macroclemys temminckii*
Texas Horned Lizard	*Phrynosoma cornutum*
Louisiana Pine Snake	*Pituophis melanoleucus ruthveni*
Bachman's Sparrow	*Aimophila aestivalis*
White-faced Ibis	*Plegadis chihi*
Southeastern Myotis	*Myotis austroriparius*
Eastern Big-eared Bat	*Plecotus rafinesquei*
Black Bear	*Ursus americanus*

Three of these species have been seen by Brantley at LHAAP. As previously documented the alligator snapping turtle has been seen at LHAAP on numerous occasions. Bachman's sparrow has been sighted a total of five times by Brantley at the following locations: Water Tower Hill, Haystack Road, Key

Ranch Road and Starr Ranch. Lastly, the Louisiana pine snake has been seen at LHAAP.

In addition to these category 2 listings, the Clasping Goldenrod (*Solidago auriculata*) is considered by the U.S. Forest Service as rare in east Texas but was found by Hine and Van Kley (1994) in the Caddo Lake State Park and Wildlife Management Area.

A REVIEW OF THE ALLIGATOR SNAPPING TURTLE (*Macroclemys temmincki*) AT LONGHORN ARMY AMMUNITION PLANT

Due to the fact that the alligator snapping turtle is apparently common at LHAAP and is on the state threatened list and is a federal category 2 candidate species, a detailed review of its life history and status has been included in this report.

The alligator snapping turtle (*Macroclemys temmincki* Gray 1835) is one of possibly 17 species of turtles that occur in Caddo Lake and LHAAP. In the popular literature and media it is certainly famous for its huge size, fishing "lure" on its tongue, and powerful jaws. The alligator snapper was reviewed in 1983 by the United States Fish and Wildlife Service for possible listing on either the federal threatened or endangered species lists. The request was denied, however the species is considered a category 2 candidate (USFWS 1994). Tom Brantley and others at and around LHAAP have seen the species numerous times, thus LHAAP might be a good location to attempt a species conservation program. The purpose of this report is to summarize the biology of the alligator snapping turtle and its known occurrences at LHAAP.

Taxonomic Relationship

The alligator snapping turtle is a vertebrate classified in the Class Reptilia, Order Testudinata (turtles), and Family Chelydridae (snapping turtles). It is one of two species of snapping turtles found in Texas, the other being the common snapping turtle (*Chelydra serpentina*). Snapping turtles are aquatic turtles that occur throughout much of the United States and can be distinguished from other aquatic turtles by a cross-shaped plastron and long tails (Blair et al. 1968). The alligator snapping turtle can be distinguished from the common snapping turtle by the presence of a row of carapace supramarginal scutes between the marginal and pleural rows of scutes. Also, the alligator snapping turtle has a larger, more strongly hooked beak.

Distribution and Population

The alligator snapping turtle range includes 14 states from Kansas to Georgia and Florida along the Gulf Coast to Texas. The core population and highest numbers appear to be in Louisiana, Mississippi, Alabama, and Florida with the other states having secondary and peripheral populations (Pritchard 1989). Studies indicate that the species is retreating from the western part of its range (Pritchard 1989).

Distribution of the species in Texas is known only from various fragmentary reports. It has been thought to occur as far west as the San Antonio and Colorado River systems but that data is not strong (Pritchard 1989). Dixon (1987) indicates that it has been found in 21 counties in extreme east Texas, which corresponds to the Sabine, Neches, Trinity, Brazos, Red and Cypress River systems. He reports the species from Marion and Harrison Counties but gives no details. Pritchard (1989) stated that Caddo Lake provides important habitat to the remaining populations in this region.

In the ecological survey at LHAAP, it was found that Tom Brantley and others have seen the alligator snapping turtle at least eight times beginning in 1975. The most numerous sightings have occurred in the northern and eastern areas of the plant, especially in or near Harrison Bayou. Other locations include the Starr Ranch, Goose Prairie Creek, the mill house area, small tributaries, and roadside drainage ditches. From personal observations, Brantley (1995) has estimated that LHAAP has a population of about 200 alligator snapping turtles. Pritchard (1989) has remarked that it has been very difficult for scientists to estimate its population size using a scientific method. He states, "If only data gathered by such individuals were admissible, we would have to declare the species already extinct."

Habitat

Rivers and large streams are reported most often to be the natural habitat of the alligator snapping turtle. However, Pritchard (1989) believes that a large population exists in Toledo Bend Reservoir which is located on the Sabine River along the Texas-Louisiana state line. It probably prefers slowly moving backwater, which is a common habitat type at Caddo Lake. Parts of LHAAP also should provide a large amount of this type of habitat. Sightings by Tom Brantley on LHAAP include the relatively large Harrison Bayou, the much smaller Kamack Creek, and even shallow roadside drainage ditches. It moves primarily along the flooded ditches.

Habitat Alteration

The most serious alteration of alligator snapping turtle habitat is probably the damming of the many rivers in its range. Dams probably intercept the upstream or downstream migrations of the animals and thus may lead to the localized extinction of the species. Other habitat alterations of potential significance include water pollution, dredging and land-use activities near its rivers. Pritchard (1989) suggests that pollution could be a problem for the alligator snapping turtle but that no one knows the specific type of pollution involved.

Size

The alligator snapping turtle is the largest freshwater turtle in North America and probably the Western Hemisphere (Pritchard 1989). The carapace length reaches 70-80 cm and is about 60 cm in width. Specimens have been documented that weigh over 300 pounds. Mature males usually are larger and heavier than mature females. Individuals probably grow slowly throughout their lifetime.

Diet and Feeding Mechanisms

Although little work has been done on juvenile alligator snapping turtles, it is generally believed that juveniles feed mostly on fish that are attracted by the use of its vermiform "lure" on its tongue (Pritchard 1989). Experiments indicate that luring is primarily a response to visual cues and not chemical cues. In feeding the turtle remains motionless with its mouth opened as much as 70° and wiggles its lure. It waits patiently for fish to enter its mouth and then quickly and powerfully shuts its jaws. If the prey is small enough, it is swallowed whole. Its front legs have been known to be used for manipulation of larger sized prey.

As the turtle ages, it gradually abandons its dependency on the lure for attracting prey. Instead, it probably feeds by an ambush method. Tom Brantley at LHAAP has witnessed adult turtles feeding in shallow ditches by stirring up the bottom sediment with its legs and feeding on organisms that are brought up.

In captivity adult turtles are known to eat fish, beef, pork, other turtle species, frog, snake, snail, worm, mussel, and even aquatic grasses. Stomach analysis of wild specimens has revealed that they eat fish, acorns, berries, ducks, crayfish, and crabs (Pritchard 1989).

Reproduction

From studies in Louisiana, sexual maturity is probably not reached until the alligator snapping turtle is 11 to 13 years old (Pritchard 1989). Dobie (1971) found active sperm in the testes throughout much of the year. Therefore, it is possible for copulation and fertilization to occur at any time with the sperm being stored by the female until needed. Sperm storage has been reported in other turtle species. Eggs are laid in the spring (April to June) with the average clutch size being about 34 eggs (Ewert 1976). The eggs are spherical, about 34-36 mm in diameter, and weigh about 25 g (Pritchard 1989). It is important to note that females lay eggs only once per year and they may skip years. Tom Brantley has seen the turtles laying eggs at numerous locations on LHAAP.

Nesting sites are on any high area near water. Ewert (1976) found nesting sites vary from unshaded and dry areas to shaded and moist areas. Small pits are dug by the female and as the eggs are laid some of the excavated material is put on top of them. Egg laying occurs during the day, preferable in the morning, over a period of a few hours. As in many other reptile species, the nest temperature determines the sex of the offspring with hotter temperatures producing all females.

It is important to note that the species does not reproduce quickly or in great numbers, which should influence decisions made about its conservation status.

Conservation Status

In February 1984 there was enough concern about the species that the U.S. Fish and Wildlife Service reviewed the species for possible listing on the threatened or endangered species lists. Their decision was not to list the species at that time, but to assign it as a category 2 candidate species. These are species for which there is some evidence of vulnerability but of insufficient amount to support listing at the time. In 1991, the U.S. Fish and Wildlife Service suggested that the status of the species be reviewed again in 1995, particularly if the states in its range do nothing additional to protect the species.

Seven of the 14 states that the alligator snapping turtle probably exists in have some type of law or regulation protecting the species. In Texas the alligator snapping turtle was placed on its threatened list on March 1, 1987 by the Texas Parks and Wildlife Commission under 31 T.A.C. Section 65.171 - 65.177 (USFWS 1991). In Louisiana there are no laws or regulations that protect the turtle. The only form of protection for the alligator snapping turtle in Louisiana is a regulation that prohibits the taking of turtle eggs (except *Pseudomys* sp.)

Conclusions

The alligator snapping turtle is not on the brink of extinction, however there is evidence that its populations are declining across its range (Pritchard 1989). The reasons for its decline are not entirely clear, but may include habitat loss, fragmentation, and degradation; unregulated commercial taking; and possibly pollution. From numerous sightings by Tom Brantley and others at LHAAP, it is possible that the Cypress Bayou basin has one of the largest remaining populations of alligator snapping turtles in the state of Texas. Due to the fact that LHAAP is on the National Priorities List, that there are potentially large populations of alligator snapping turtles on LHAAP, and knowing the life history of the turtle, the species is a great candidate for use as an environmental receptor of concern.

TASK 3
GENERAL DESCRIPTION OF MAJOR PLANT ASSOCIATIONS

VEGETATION PROFILE OF NORTHEAST TEXAS

The work of Campo (1986) serves as an excellent overview to the vegetation of the northeast Texas region, including the watershed of Big Cypress Bayou and LHAAP. The area encompasses 2855 square miles (1,827,218 acres, Appendix 2). A total of seven vegetation-land use types was identified in the Big Cypress Wildlife Unit based on classified Landsat data (image in Appendix 3).

VEGETATION TYPE	ACRES	PERCENT OF UNIT
Pine-Hardwood Forest		
1) Pine/Pine Hardwood Forest	348,632	19.0
2) Hardwood-Pine Forest	347,297	19.0
3) Young Pine Forest/Mixed Brush	177,498	9.7
TOTAL	**873,427**	**47.7**
Grassland	**448,782**	**24.6**
Bottomland Hardwood Forest		
1) Mixed Hardwood Bottomland Forest	308,840	16.9
2) Bald Cypress Swamp/Flooded Hardwood	9,957	0.5
TOTAL	**318,806**	**17.4**
Upland Hardwood Forest (Post Oak-Blackjack Oak Forest)	**79,551**	**4.4**
Cropland (wheat, soybeans, corn, vegetables, pecans)	**36,780**	**2.0**
Water	**34,072**	**1.9**
Urban & Sparsely Vegetated		**0.8**
Unclassified		**1.1**

VEGETATION ANALYSIS OF LHAAP

LHAAP is part of the Cypress Bayou Basin and occurs within the Pineywoods ecological region of Texas (Gould 1975). The elevation of the site ranges from 168.5 feet mean sea level to 335 feet msl (USGS 1978). As a result of this topography, there is a great diversity of habitats, including mesic slopes, mesic creek bottoms, bottomland flats, and wetlands. This diversity of vegetation and its accompanying ecotones suggests that there are potentially large numbers of species present in the area.

The vegetation of LHAAP has been classified by the National Biological Service, Southern Science Center (NBS-SSC, Lafayette, LA) using Thematic Mapper (TM) data from January 30, 1993. Groundtruthing (GT) was done by members of The Caddo Lake Institute during the fall of 1994 at about 80 sites throughout the Caddo Lake drainage basin. Classification of the vegetation follows the Louisiana GAP scheme with 12 main categories, several of which are subdivided into three or four subtypes (Appendix 4). At each GT site, a data form (Appendix 5) was completed and a photograph was taken for a permanent record. These were sent to NBS for interpretation and data entry into a geographic information system (GIS) by their staff. In order to obtain more accurate data for this contract on LHAAP, NBS requested additional groundtruthing at 31 sites on LHAAP property. Based on GT work done in both the fall and spring, the following represents the classification of 8512 acres on LHAAP.

VEGETATION TYPE	ACRES	%
Forest -- Mixed	3478.894	40.87
Forest -- Evergreen	1917.755	22.53
Swamp -- Deciduous	1808.716	21.25
Vegetated Urban	760.646	8.94
Shrub/Scrub -- Mixed	527.124	6.19
Swamp -- Mixed	176.377	2.07
Forest -- Deciduous	176.223	2.07
Dense Pine Thicket	85.100	1.00
Grassland	46.179	0.54
Water	27.800	0.33
Shrub/Scrub -- Deciduous	27.646	0.32
Agriculture -- Cropland	6.641	0.08
Shrub/Scrub -- Evergreen	0.000	0.00
Marsh	0.000	0.00
Swamp -- Evergreen	0.000	0.00
Non-Vegetated Urban	0.000	0.00
Barren	0.000	0.00
Out/Background	2601.950	0.00
	8511.977	100.00

GENERAL DESCRIPTION OF MAJOR PLANT ASSEMBLAGES ON LHAAP

According to the GIS analysis, LHAAP is dominated by about 63% evergreen and mixed upland forest, representing about 5300 acres, and another 21% by deciduous forested swamp. The remaining 16% of the cover is represented by eight different vegetation types, with vegetated urban being the most common at almost 9%. The following represents a general description of each cover type that was classified on LHAAP.

1) **Mixed Forest**: This assemblage composes almost 41 percent of the vegetation cover on the plant. It is dominated by hardwoods such as sweetgum, red oak, cherrybark oak, post oak, black hickory, mockernut hickory, water oak, willow oak, black oak, white oak, hackberry, red maple, and winged elm. Pine species present include loblolly, slash, longleaf and shortleaf. The midstory is dominated by flowering dogwood, American hornbeam, American holly, hophornbeam, eastern redbud, laurelcherry, sassafras, viburnums, yaupon holly, southern waxmyrtle, American beautyberry, red buckeye, and farkleberry. Groundcover vegetation consists mostly of vines such as peppervine, Japanese honeysuckle, Virginia creeper, greenbriar, poison ivy, grape, yellow jassamine, and bracket fern.

2) **Evergreen Forest**: Loblolly and shortleaf pine are the dominant trees in this assemblage which composes 23% of the classified area and is evenly distributed on LHAAP. In addition to pines, it contains small numbers of southern red oak, post oak, red maple, winged elm, and sweetgum. Tree midstory density is low and includes flowering dogwood, white sassafras, hawthorn, winged sumac, southern waxmyrtle, farkleberry, and American beautyberry, Japanese honeysuckle, poison ivy, and greenbriar dominate a sparse groundcover vegetation.

3) **Deciduous Swamp**: These areas are subject to periodic flooding, sometimes at long intervals. Much of this represents bottomland hardwoods and forms about 21% of the classified area. It is dominated by large tree species such as water hickory, water oak, green ash, water tupelo, and baldcypress. This area occurs mostly along Harrison Bayou, Saunder's Creek, Kamack Creek, beaver-influenced areas, and along the margin of Caddo Lake.

4) **Vegetated Urban**: This assemblage includes the vegetation around the buildings and along the roads and railroads of LHAAP and forms almost 9% of the vegetation cover.. Species found in these area include various grasses such as crab grass, Johnson grass, clovers, and typical lawn weeds such as dandelion and bitterweed. For a complete listing, see Appendix 6.

5) **Mixed Shrub/Scrub**: Comprising about 2% of the area, this vegetation assemblage includes both evergreen as well as deciduous shrub plants. Species include wax myrtle, buttonbush, cedar, sassafras, plum, hawthorn, and young pines.

6) **Deciduous Forest**: About 2% of the area is classified as deciduous forest. Species include sweetgum, various oaks, hickories, maples, and elms. Scattered pines are also found in this vegetation type.

7) **Dense Pine Thicket**: Representing only 1% of the classified area, the dense pine thicket is dominated by loblolly and short-leaf pine and generally has a sparse midstory and ground cover. These areas are probably managed areas of various ages.

8) **Grassland**: This composes 0.5% of the cover and is dominated by grasses, forbs, and grasslike plants. Crown coverage of woody vegetation is generally 10 percent or less. Species in this assemblage include: coastal bermuda grass, common bermuda grass, bahia, dallis grass, blue stem, and winter rye.

9) **Water**: This is represented by the margin of Caddo Lake, Harrison Bayou, Saunder's Branch, Kamack Creek and their many small tributaries. In addition, there are two small ponds on the plant, a brine evaporation pond and Duck Pond.

10) **Deciduous Shrub/Scrub**: Deciduous shrubs in this assemblage includes plum, sumac, and hawthorn.

11) **Cropland –Agriculture**: This includes less than 0.1% of the classified area mostly along the western and northern boundaries. The variety of crop being grown is not known.

The above descriptions provide a brief overview of the eleven plant associations on LHAAP. A more detailed analysis based on forest management units as delineated by Brantley (1995) is shown in Appendix 6 and a listing of grasses, herbs, and trees on LHAAP is in Appendix 7.

VEGETATION OF HARRISON BAYOU

Of special interest on LHAAP is the Harrison Bayou area of about 1086acres. In 1977 a team of foresters from Stephen F. Austin State University and Tom Brantley conducted vegetation and wildlife surveys of the bottomland hardwood forest and baldcypress swamp of LHAAP along Harrison Bayou. The area was being considered by the U.S.. Army as a "special management area". Though no official action was taken regarding the designation, the area has been set aside from logging and development actiivities (Burkett 1994).

Harrison Bayou represents one of the few old-growth bottomland hardwood forests left in Texas and the southern United States. According to National Wetlands Inventory (NWI) data, the U.S. has loss approximately one-half of the wetland acreage that existed in the lower 48 states prior to European settlement (Mitsch and Gosselink 1993). During the 200 year span from 1780 to 1980, over 24 hectares of wetlands were lost every hour. The Nature Conservancy (1992) has estimated that from 1883 to 1991 the southern bottomland hardwood forest acreage decreased by 77%. The 23% that remain is being fragmented and has lost many of the original functions. By 1980, the original extent of bottomland hardwood forests in Texas had been reduced by 63%, from roughly 6.5 million hectares to 2.5 million hectares (Dahl 1990; Frye 1986). In response to these historical trends, the Harrison Bayou area should continue to be protected and studied. In addition, Burkett (1994) has stated that Harrison Bayou represents a model southern bottomland hardwood wetland in both structure and ecological function.

Burkett (1994) stated that Harrison Bayou drains about 7000 km^2 and can be divided into six distinct plant associations based on slope and hydrology: 1) cherrybark oak-overcup oak-baldcypress-sweetgum, 2) pine-hardwood, 3) open flats, 4) overcup oak, 5) cherrybark oak-sweetgum, and 6) water elm-baldcypress-swamp privet-overcup oak-baldcypress. Also it should be noted that the national champion water hickory (*Carya aquatica*) which is 89 feet tall, the national champion blueberry hawthorn (*Crateagus brachyacantha*), and the former state champion flowering dogwood (*Cornus florida*) are all located on LHAAP property. A more complete description of Harrison Bayou is provided in Appendix 8.

Tom Brantley (1995) with the aid of the National Biological Service completed a survey of the ecotones and virgin timber of Harrison Bayou. The areas were outlined on a LHAAP map, digitized and then put into a geographical information system (GIS). The greatest ectone acreage (39.9%) was the cherrybark oak-water oak-sweetgum association (Figure 1). Seven different areas representing 488 acres of virgin timber were delineated (Figure 2).,

VEGETATION ANALYSIS OF CADDO LAKE STATE PARK AND WILDLIFE MANAGEMENT AREA

In the adjacent 480 acre Caddo Lake State Park and 7500 acre Wildlife Management Area with very similar topography and climate, Hine and Van Kley(1994) have compiled a list of 297 vascular plant species (Appendix 9). Due to similarity of climate, topography, and soils, most, if not all, of these species would be expected to exist on LHAAP. In addition to these species, an additional 42 species of aquatic plants have been found in Caddo lake by personnel of the Inland Fisheries Branch of the TPWD (Appendix 10).

SUMMARY AND CONCLUSIONS

This report summarizes ecological information collected at Longhorn Army Ammunition Plant (LHAAP) at Karnack, Texas beginning in the fall of 1994 by The Caddo Lake Institute. The 8500 acre facility was built in 1943 by the U.S. Army and is operated by its contractor Thiokol Corporation. The facility was listed on the National Priorities List (Superfund) on August 30, 1990, and cleanup operations have already begun at selected areas of the facility.

LHAAP is part of the Cypress Bayou Basin and lies on the shores of Caddo Lake. The climate is generally subtropical with hot, humid summers and mild winters. Topography of the plant is relatively flat with a number of uplands separated by numerous drainages. LHAAP occurs within Gould's Pineywoods ecological region of Texas.

The property is dominated by forests, including mixed pine-hardwood forests, pine forests, and bottomland hardwood forests. In addition, there are areas that are large tracts of virgin timber, particularly along Harrison Bayou, and two present and one former champion trees. The property is rich in animal life in that a total of 465 vertebrate species could possibly occur either on LHAAP or in adjacent Caddo Lake. This fauna represents an impressive 38% of the vertebrate species that have been documented in the state of Texas. A complete, on-site species inventory of LHAAP should be done in order to verify the presence of these species. This is especially true of the fish fauna in that there has been no previous attempt to document the fish fauna of the streams and other aquatic habitats on the plant. Although identification of invertebrate and lower plant species were not considered to be an objective of the study, there appears to be little known about these groups.

There were 11 of 21 possible endangered or threatened species identified as possibly being on or near LHAAP. Due to the fact that LHAAP is an NPL site and has limited access, there could be a significant opportunity to better manage and conserve these species. In addition, the Harrison Bayou area is a significant natural resources due to the fact it contains tracts of virgin timber and represents a model southern bottomland hardwood forests.

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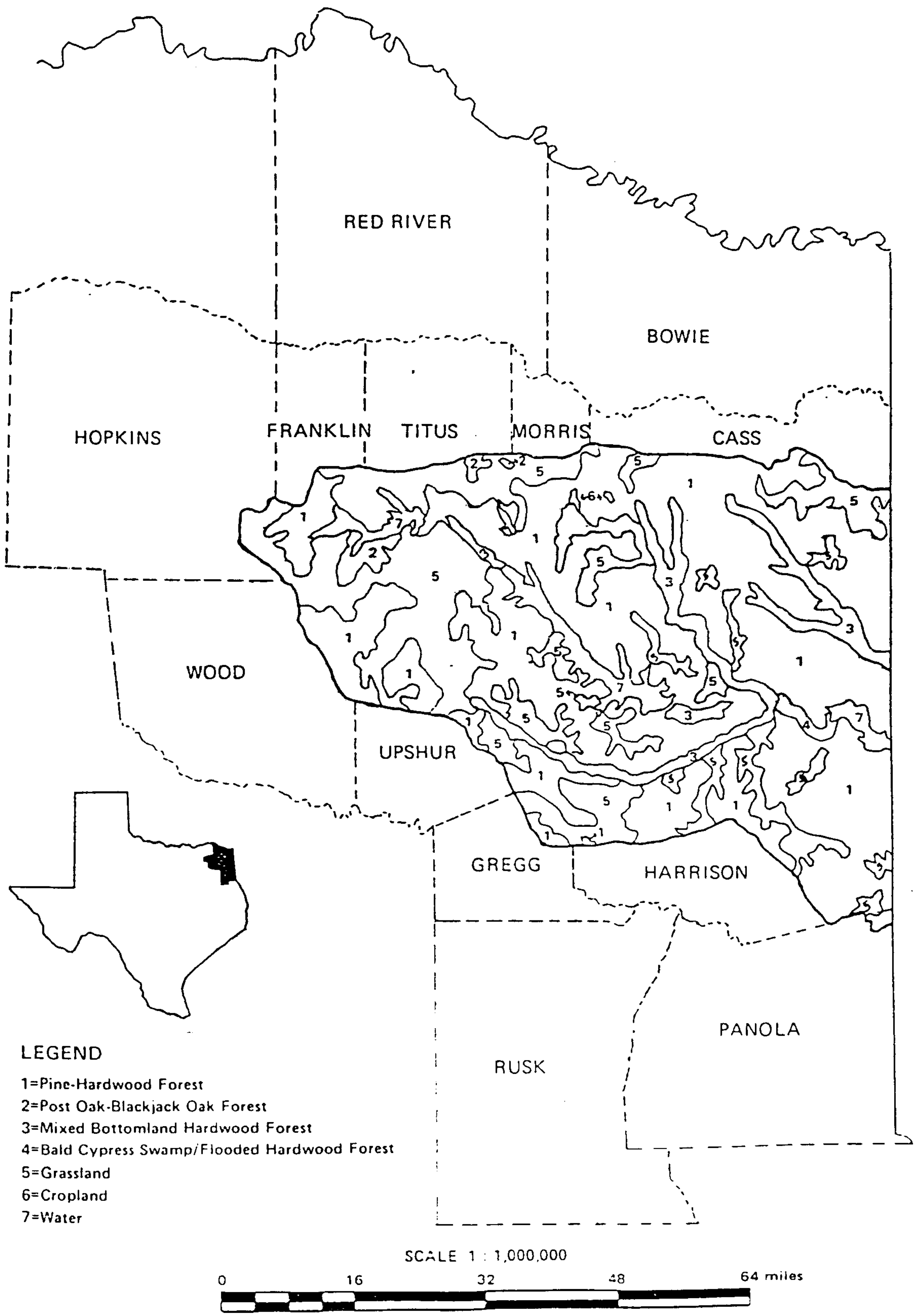
APPENDIX 2
VEGETATION MAP OF THE BIG CYPRESS WILDLIFE UNIT



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APPENDIX 3
CLASSIFIED IMAGERY OF LONGHORN ARMY AMMUNITIONS PLANT
THEMATIC MAPPER DATA -- JANUARY 30, 1993

APPENDIX 4
LOUISIANA GAP CLASSIFICATION SCHEME

1. Marsh - Black Rush/Wire Grass/Three Corner Grass/Bulltongue/Spikerush
2. Swamp (Forested)
   a. Deciduous - Water Hickory, Water Oak & Green Ash or Water Tupelo/Bald Cypress
   b. Evergreen - Atlantic White Cedar or Magnolia
   c. Mixed - Water Oak/Live Oak
3. Forest (Upland)
   a. Deciduous - Red Oak Group/Sweetgum
   b. Evergreen - Slash/Longleaf Pine
   c. Mixed - Sweetgum/Slash Pine
4. Dense Pine Thicket (Upland)
   Pine Plantation
5. Shrub/Scrub (Wetland)
   a. Deciduous - Button Bush or Marsh Elder
   b. Evergreen - Bay/Wax Myrtle/Groundselbush/Palmetto
   c. Mixed - Button Bush/Wax Myrtle
6. Shrub/Scrub (Upland)
   a. Deciduous - Sumac or Plums or Hawthorne
   b. Evergreen - Yaupon/Wax Myrtle or Gallberry
   c. Mixed - Hawthorne/Yaupon/Privet
7. Agriculture - Cropland
   Soybeans/Cotton/Sugarcane/Rice/Orchards - Pecan/Tung nut
8. Grassland
   Wiregrass/Broomsedge/Blue Stem/Winter rye
9. Vegetated Urban
   a. Deciduous - Red Oak group & Pecan & Cedar
   b. Evergreen - Live Oak & Magnolia/Pine
   c. Mixed - Pine & Red Oak group
   d. Brush/Shrub - Azaela & Crape Myrtle
10. Non-Vegetated Urban
11. Barren
12. Water

In addition to the dominant and co-dominant species labels for each vegetation polygon, the following point data will be obtained from ground truthing of the classifications. This additional information will be obtained for point locations and will be overlaid on the vegetation maps.

a) For three layers in the vegetative matrix - herbaceous (ground), middle, and canopy - a 1-3 rank will correspond to sparse (<25%), medium (25-65%), or thick density (>65%).

b) For forested areas, a ranking of 1-3 for the average of five largest tree trunk diameters: for small (<8 inches), medium (8-18 inches), and large (>18 inches).

APPENDIX 5
GAP FIELD SURVEY SHEET FOR CADDO LAKE DRAINAGE BASIN

DATE:____________________
SURVEY TEAM MEMBERS:____
SITE NUMBER:_______ MAP NAME:________________ PHOTO FRAME NUMBER:___________
STATE:____________ COUNTY/PARISH:____________________________

WHAT IS THE GAP CLASSIFICATION AT SITE:____

LIST OF THE DOMINANT VEGETATION AT SITE(common name or scientific name):
DOMINANT UPPER CANOPY LEVEL____

UNDERSTORY____

CANOPY COVER IN PERCENT:
UPPER CANOPY___________
UNDERSTORY_____________
IF A SWAMP, FOREST, SHRUB-SCRUB OR DENSE PINE THICKET CLASSIFICATION GIVE APPROXIMATE AVERAGE HEIGHT IN FEET OF DOMINANT AND/OR UNDERSTORY CANOPY:
DOMINANT__________ UNDERSTORY__________

SURFACE WATER:
PRESENT_______
NOT PRESENT_______

LAND USE ACTIVITY (Response for vegetated & non-vegetated urban, Agriculture-cropland, Grassland and Barren classification:____

PHOTOGRAPH TAKEN:
YES______ IF YES HOW MANY FRAMES?_______
LOOK DIRECTION OF PHOTOGRAPHS (North, South, East. West, & etc.)____________________
NO_______

VEGETATION LAYERS (ESTIMATED):**

GROUND (HERBACEOUS)	____0-25% (sparse)
	____26-65% (medium)
	____66% and More (thick)
MIDDLE CANOPY	____0-25% (sparse)
	____26-65% (medium)
	____66% and More (thick)
UPPER CANOPY	____0-25% (sparse)
	____26-65% (medium)
	____66% and More (thick)

FOR FORESTED AREAS, A RANKING OF 1-3 FOR THE AVERAGE OF FIVE LARGEST TREE TRUNK DIAMETERS:**
(1)SMALL < 8 INCHES____
(2)MEDIUM 8-18 INCHES____
(3)LARGE > 18 INCHES____

**OBTAIN THIS INFORMATION ONLY WHEN YOU HAVE PROPER ACCESS TO THE PROPERTY

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APPENDIX 6
LHAAP FOREST MANAGEMENT MAP

APPENDIX 7
GRASSES, HERBS, AND TREES OCCURRING ON LONGHORN ARMY AMMUNITION PLANT (LHAAP 1993)

The following represents the common and scientific names of grasses, herbs, and trees found on LHAAP by Brantley. The list includes 32 species of grasses and herbs and 101 species of trees. Nomenclature follows Vines (1977).

Common Name	Scientific Name
Grasses and Herbs	
Broomsedge Bluestem	*Andropogon virginicus*
Bermuds	*Cynodon dactylon*
Switch Cane	*Arundinaria tacta*
Crab Grass	*Digitaria sanninalis*
Dallis Grass	*Paspalum dialatatinum*
Vasey Grass	*Paspalum urvillei*
Signal Grass	*Brachiaria sp.*
Johnson Grass	*Sorghum halepense*
Crimson Clover	*Trifolium incarnatum*
Ball Clover	*Trifolium nigresens*
White Clover	*Trifolium repens*
Partridge Pea	*Cassia faciculata*
Beggar Weed	*Desmodium tortuosum*
Hemp Sesbania	*Sesbania exaltata*
Rattle Box	*Sesbania vesicaria*
Common Ragweed	*Ambrosia artemisiifolia*
Giant Ragweed	*Ambrosia trifida*
Pokeberry	*Phytacca americana*
Whiteheath Aster	*Aster pilosus*
Bitterweed	*Helinium amarum*
Dandelion	*Taraxacum officinale*
Goldenrod	*Solidago sp.*
Lambs Quarters	*Chenopodium album*
Horseweed	*Erigeron canudensis*
Nutsedge	*Cyper sp.*
Maypop	*Passiflora incarnata*
May Apple (Mayflower)	*Podophyllum peltatum*
Yellow Woodsorrel	*Oxalis stricata*
Dockweed	*Rumex sp.*
Poorjoe	*Diodia teres*
Horse Nettle	*Solanum carolinense*
Jimson Weed	*Datura stramonium*
Trees and Shrubs	
Shortleaf Pine	*Pinus echinata*
Loblolly Pine	*Pinus taeda*
Longleaf Pine	*Pinus palustris*
Slash Pine	*Pinus elliottii*

Common Name	Scientific Name
Baldcypress	*Taxodium distichum*
Eastern Red Cedar '	*Juniperus virginiana*
Eastern Cottonwood	*Populus deltoides*
Black Willow	*Salix nigra*
Dwarf Palmetto	*Sabal minor*
Black Walnut	*Juglans nigra*
Pecan	*Carya illinoensis*
Bitter Pecan	*Carya aquatica*
Mockernut Hickory	*Carya tomentosa*
Pignut Hickory	*Carya glabra*
Black Hickory	*Carya texana*
Bitternut Hickory	*Carya cordiformis*
River Birch	*Betula nigra*
Blue Beech	*Carpinus caroliniana*
American Hophornbeam	*Ostrya virginiana*
Overcup Oak	*Quercus lyrata*
White Oak	*Quercus alba*
Basket Oak (Cow Oak)	*Quercus michauxii*
Post Oak	*Quercus stellata*
Willow Oak	*Quercus phellos*
Water Oak	*Quercus niger*
Blackjack Oak	*Quercus marilandica*
Southern Red Oak	*Quercus falcata*
Shumard Red Oak	*Quercus shumardii*
Black Oak	*Quercus velutina*
Sugar Hackberry	*Celtis laevigata*
Winged Elm	*Ulmus alata*
Cedar Elm	*Ulmus crassifolia*
Slippery Elm	*Ulmus rubra*
Water Elm	*Planera aquatica*
Red Mulberry	*Morus rubra*
Osage-orange (Bois D'arc)	*Maclura pomifera*
Sassafras	*Sassafras albidum*
American Sweetgum	*Liquidambar styraciflua*
Sycamore (American Plane-tree)	*Platanus occidentalis*
May Hawthorn (Mayhaw)	*Crataegus opaca*
Blueberry Hawthorn	*Crataegus brachyacantha*
Parsley Hawthorn	*Crateagus marshallii*
Green Hawthorn	*Crateagus viridis*
Mexican Plum	*Prunus mexicana*
Eastern Redbud	*Cercis canadensis*
Honey Locust	*Gleditsia triacanthos*
Water Locust	*Gleditsia aquatica*
Black Locust	*Robina pseudo-acacia*
American Holly	*Ilex ameriana*
Possum-haw Holly (Deciduous Holly)	*Ilex decidua*
Yaupon Holly	*Ilex vomitoria*
Red Maple	*Acer rubrum*

Common Name	Scientific Name
Sugar Maple	*Acer saccharum*
Box-elder Maple	*Acer negundo*
American Linden (Basswood)	*Tilia americana*
Flowering Dogwood	*Cornus florida*
Black Tupelo (Blackgum)	*Nyssa sylvatica*
Woollybucket Bumelia (Gum Bumelia)	*Bumelia lanuginosa*
Common Persimmon	*Diospyros virginiana*
Common Sweetleaf	*Symplocos tinctoria*
Two-wing Silver-Bell	*Halesia diptera*
Green Ash	*Fraxinus pennsylvanica*
Catalpa	*Catalpa bignonioides*
China-berry	*Melia azedarach*
Hercules-club (Toothache Tree)	*Zanthoxylum clava-herculis*
American Elm	*Ulmus americana*
Wax Myrtle	*Myrica cerifera*
Chickasaw Plum	*Prunus angustifolia*
Crab Apple	*Pyrus angustifolia*
Flame-leaf Sumac (Winged Sumac)	*Rhus copallina*
Smooth Sumac	*Rhus glabra*
Carolina Buckthorn	*Rhamnus caroliniana*
Rusty Blackhaw Viburnum	*Viburnum rufidulum*
Red Buckeye	*Aesculus pavia*
Devil's Walkingstick	*Aralia spinosa*
Farkleberry (Tree Huckleberry)	*Vaccinium arboreum*
Elliott Blueberry (Summer Huckleberry)	*Vaccinium elliottii*
Texas Forestiera (Swamp Privet)	*Forestiera acuminata*
Japanese Privet (Common Privet)	*Ligustrum japonicum*
Strawberry Bush	*Euonymus americana*
White Fringe Tree	*Chionanthus virginicus*
Trifoliate Orange	*Poncirus trifoliata*
Pawpaw	*Asimina triloba*
St. Andrew's Cross	*Hypericum hypericoides*
French Mulberry	*Callicarpa americana*
Elderberry	*Sambucus canadensis*
Eastern Baccharis	*Baccharis halimifolia*
Poison Ivy	*Toxicodendron radicans*
Poison Oak	*Toxicodendron quercifolia*
Pepper Vine	*Ampelopsis arborea*
Grape	*Vitis sp.*
Virginia Creeper	*Parthenocissus quinquefolia*
Greenbriar	*Smilax sp.*
Alabama Supplejack (Rattan)	*Berchemia scandens*
Honeysuckle	*Lonicera japonica*
Trumpet Creeper	*Campsis radicans*
Cross Vine	*Bigonia capreolata*
Yellow Jasmine	*Gelsemium sempervirens*
McCartney Rose	*Rosa bracteata*
Cherokee Rose	*Rosa laevigata*

APPENDIX 8
AN OVERVIEW OF HARRISON BAYOU ON LHAAP

Of special consideration on LHAAP is the Harrison Bayou area which occupies about 1000 acres on the plant. For various reasons, little activity has occurred in this area since the turn of the century. Beginning in the mid-1970s the U.S. Army and Thiokol Corporation have managed the Harrison Bayou tract as an unofficial "special management area". The purpose of this report is to provide a brief characterization of Harrison Bayou on LHAAP. This area and the lower end of the Saunder's Creek drainage contain virgin stands of hardwoods that date back to the 1830s when the water level of Caddo Lake dropped due to the breaking of the downstream logjam.

Geology and Soils

Harrison County is in the West Gulf Coastal Plain Physiographic Province (Golden et al. 1994). The oldest geologic materials on the surface of the eastern part of the county are those of the Wilcox group of Eocene age. The sediments were deposited about 40 to 60 million years ago and are as much as 1,000 feet thick. The sediments consist of fine and medium, crossbedded sand, shale, clay, lignite, and some minor amounts of other materials. The accumulation of pedisediments during the Pleistocene may have contributed to a thin layer of loamy sediments.

At LHAAP there are two general soil types: Scottsville, which covers most of the plant and Iuka-Socagee-Sardis, which is in the Harrison Bayou drainage (Golden et al. 1994). Scottsville soils are nearly level, moderately drained, loamy soils located on the uplands. The Iuka-Socagee-Sardis soils are nearly level flood plains along streams. They are loamy soils subject to being wet for extended periods of time

Within the county there are two major aquifers Carrizo-Wilcox and Queen City-Reklaw, which are probably interconnected (Golden et al. 1994). They are known as the Cypress basin and Sabine basin, respectively. The Carrizo-Wilcox is the lowest, largest, and most productive of the two. Both are recharged by rainwater infiltration in their outcrop areas. Harrison Bayou is a secondary stream that arises from groundwater sources of the Carrizo-Wilcox aquifer near Scottsville in Harrison County and flows northeast for about 14 miles until it empties into Caddo Lake at Harrison Bay.

Archaeology

Humans have probably inhabited the area now known as Harrison County for about 12,000 years. The Caddo Indians lived here beginning around 600 A.D. Their culture is represented by settled villages, advanced agricultural practices, and the use of pottery. The typical Caddoan house was circular with a large entrance. They grew maize, beans, and squash on the nearby flood plains and utilized the forest and aquatic resources of the area. Artifacts of the culture include points, darts, polished stone, and engraved ceramics (Golden et al. 1994). Pieces of pottery and arrowheads have been found in several locations along cliffs overlooking Harrison Bayou by Tom Brantley and others. Site numbers for these sites are ARC1 and ARC2 as shown on the species sightings overlay and explained more fully in the field notes (Appendix 9).

Site History and Characterization

Water levels and vegetation communities of Harrison Bayou are largely determined by the water level in Caddo Lake. Over the past 200 years the lake level has changed drastically several times due to logjam and its removal and by the building of the dam by the Corps of Engineers in 1914. The present-day Harrison Bayou wetland probably arose following the lowering of the lake level after the logjam was removed completely in 1873.

It is generally believed that much of the forest along Harrison Bayou has not been subject to logging since around the turn of the century. Although logging was widespread in the region during this time period, a number of factors limited logging activities. Difficulties encountered by the loggers include the area's relative inaccessibility, the presence of old stream channels, and frequent periods of flooding. In 1942 the federal government purchased the area now known as LHAAP from several local families. Just before the purchase, some of the property was selectively harvested along Harrison Bayou but much of the area was left undisturbed.

In 1969 the U.S. Army adopted a Comprehensive Natural Resource Management Plan for LHAAP. The plan allowed for selective harvesting of timber along the bayou. Due to the uniqueness of Harrison Bayou forests, the harvesting schedules were altered in 1973 so that no old-growth timber would be cut. Studies conducted in 1977 by the Department of Forestry at Stephen F. Austin State University recommended to the Department of Defense the designation of Harrison Bayou old growth virgin forest as a forest preserve. Recently, portions of LHAAPs bottomland hardwoods and other nearby wetlands were delineated by the National Wetlands Inventory and designated as Resource Category 1 Habitat by the USFWS.

Vegetation

The vegetation along Harrison Bayou has been classified as palustrine forest wetland by the National Wetlands Inventory (NWI 1980). NWI classification criteria are hydric soils, vegetation types, and frequency of flooding. Palustrine forests are defined as "all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5‰. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 hectares (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 m at low water; and (4) salinity due to ocean-derived salts less than 0.5 ‰ "(Cowardin et al. 1979).

In general, the vegetation is composed of southern baldcypress and other bottomland hardwood species. In Harrison Bayou there is approximately a 120 hectare tract of palustrine wetland that is thought to be virgin. This area adjoins other important tracts of secondary growth bottomland hardwoods totaling roughly 300 hectares. Burkett (1994) stated that the Harrison Bayou area can be divided into six distinct plant associations based on the slope and hydrology: 1) cherrybark oak-overcup oak-baldcypress-sweetgum, 2) pine-hardwood, 3) open flats, 4) overcup oak, 5) cherrybark oak-sweetgum, and 6) water elm-baldcypress-swamp privet-overcup oak-baldcypress. The zonation between these associations is related to the soils, water regime, and topography.

Summary and Conclusions

Historically and ecologically, Harrison Bayou has been and is still important to the Caddo Lake watershed. This area provides one of the last remaining old-growth bottomland hardwood forests in the southern United States. It consists of six plant associations which are defined by the soils, water regime, and topography. In the past the area was protected for a variety of natural reasons, but since 1969 it has been protected by the U.S. Army. That protection needs to continue in order to protect this valuable natural resource. The area also can serve as a natural laboratory for a variety of research projects which can aid in the increased understanding of this type of ecologically significant wetland.

APPENDIX 9
VEGETATION INVENTORY OF CADDO LAKE STATE PARK AND WILDLIFE MANAGEMENT AREA

The following is a list of vascular plants that have been identified in the field by Hine and Van Kley (1994) at Caddo Lake State Park and the Wildlife Management Area. Due to the proximity of these areas and the same basic geology, soils, and topography, it is expected that they could occur at LHAAP.

Common Name	Scientific Name
Gymnospermae	
Cupressaceae (Cypress Family)	
Eastern Red Cedar	*Juniperus virginiana*
Pinaceae (Pine Family)	
Shortleaf Pine	*Pinus echinata*
Loblolly Pine	*Pinus taeda*
Taxodiaceae (Taxodium Family)	
Baldcypress	*Taxodium distichum*
Angiospermae	
Acanthaceae (Acanthus Family)	
Lance-leaved Waterwillow	*Justicia ovata*
Stalk Ruellia	*Ruellia pedunculata*
Aceraceae (Maple Family)	
Boxelder	*Acer negundo*
Red Maple	*Acer rubrum*
Sugar Maple	*Acer saccharum*
Anacardiaceae (Sumac Family)	
Wing Rib Sumac	*Rhus copallina*
Smooth Sumac	*Rhus glabra*
Poison Ivy	*Toxicodendron radicans*
Annonacease (Custard Apple Family)	
Dwarf Pawpaw	*Asimina parviflora*
Pawpaw	*Asimina triloba*
Apiacease (Parsley Family)	
Chervil	*Chaerophyllum tainturieri*
Water Hemlock	*Cicuta maculata*
Button Snake Root Eryngo	*Eryngium yuccifolium*
Mock Bishop's Weed	*Ptilimnium capillaceum*
Nuttal Mock Bishop's Weed	*Ptilimnium nuttallii*
Canada Sanicle	*Sanicula canadensis*
Aquifoliaceae (Holly Family)	
Carolina Holly	*Ilex ambiqua*
Deciduous Holly	*Ilex decidua*
Araceae (Arum Family)	
Green Dragon	*Arisaema dracontium*

Common Name	Scientific Name
Araliaceae (Ginseng Family)	
Devil's Walking Stick	*Aralia spinosa*
Aristolochiaceae (Birthwort Family)	
Texas Dutchman's Pipe	*Aristolochia reticulata*
Asclepiadaceae (Milkweed Family)	
Butterfly Milkweed	*Asclepias tuberosa*
White-flowered Milkweed	*Asclepias variegata*
Asteraceae (Sunflower Family)	
Common Yarrow	*Achillea millifolium*
Common Ragweed	*Ambrosia artemisiifolia*
Giant Ragweed	*Ambrosia trifida*
Texas Aster	*Aster drummondii*
Heath Aster	*Aster ericoides*
Skydrop Aster	*Aster patens*
Tall Aster	*Aster praealtus*
Simple Aster	*Aster simplex*
Eastern Baccharis	*Baccharis halimifolia*
Hairy Green Eyes	*Berlandiera betonicifolia*
Beggarticks	*Bidens discoidea*
Awnless beggarticks	*Bidens polylepis*
Small-head Boltonia	*Boltonia diffusa*
Soft Gold Aster	*Chrysopsis pilosa*
Bull Thistle	*Cirsium horridulum*
Texas Thistle	*Cirsium texanum*
Plain Coreopsis	*Coreopsis tinctoria*
White Eclipta	*Eclipta prostrata*
Leafy Elephant Foot	*Elephantopus carolinianus*
Hairy Elephant Foot	*Elephantopus tomentosus*
Philadelphia Fleabane	*Erigeron philadelphicus*
Prairie Fleabane	*Erigeron strigosus*
Blue Mist Flower	*Eupatorium coelestinum*
Thoroughwort	*Eupatorium perfoliatum*
Eupatorium	*Eupatorium semiserratum*
Late Eupatorium	*Eupatorium serotinum*
Swamp Sunflower	*Helianthus angustifolius*
Ragweed Woollywhite	*Hymenopappus artemisiifolius*
Weedy Dwarf Dandelion	*Krigia caespitosa*
Florida Wild Lettuce	*Lactuca floridana*
Tall Gayfeather	*Liastris asper*
Pinkscale Gayfeather	*Liatris elegans*
Camphor Weed	*Pluchea camphorata*
Late Coneflower	*Rudbeckia hirta*
Great Coneflower	*Rudbeckia maxima*
Golden Groundsel	*Senecio obovatus*
Simpson's Rosinweed	*Silphium simpsonii*
Clasping Goldenrod	*Solidago auriculata*
Goldenrod	*Solidago nemoralis*
Balsaminaceae (Touch Me Not Family)	
Jewel Weed	*Impatiens capensis*

Common Name	Scientific Name
Betulaceae (Birch Family)	
River Birch	*Betula nigra*
American Hornbeam	*Carpinus caroliniana*
Eastern Hophornbeam	*Ostrya virginiana*
Berberidaceae (Barberry Family)	
May Apple	*Podophyllum peltatum*
Bignoniacease (Catalpa Family)	
Cross Vine	*Bignonia capreolata*
Trumpet Creeper	*Campsis radicans*
Boraginaceae (Borage Family)	
Early Forget-me-not	*Myosotis verna*
Brassicaceae (Mustard Family)	
Poor Man's Peppergrass	*Lepidium virginicum*
Bromeliaceae (Pineapple Family)	
Spanish Moss	*Tillandsia usneoides*
Campanulaceae (Bluebell Family)	
Earleaf Lobelia	*Lobelia appendiculata*
Cardinal Flower	*Lobelia cardinalis*
Downy Lobelia	*Lobelia puberula*
Clasping Venus Lookingglass	*Triodanis perfoliata*
Caprifoliaceae (Honeysuckle Family)	
Common Elderberry	*Sambucus canadensis*
Rusty Blackhaw Viburnum	*Viburnum rufidulum*
Caryophyllaceae (Pink Family)	
Starry Catchfly	*Silene stellata*
Clusiaceae (St. John's Wort Family)	
St. Andrew's Cross	*Hypericum hypericoides*
Turf St. John's Wort	*Triandenum tubulosum*
Walter's St. John's Wort	*Triandenum walteri*
Commelinaceae (Spiderwort Family)	
Virginia Dayflower	*Commelina virginica*
Harry Spiderwort	*Tradescantia hirsutiflora*
Cornaceae (Dogwood Family)	
Flowering Dogwood	*Cornus florida*
Blackgum	*Nyssa sylvatica*
Cyperaceae (Sedge Family)	
Smooth Sedge	*Carex blanda*
Woodbank Sedge	*Carex cephalophora*
Cherokee Sedge	*Carex cherokeensis*
Sedge	*Carex complanata*
Close-flowered Sedge	*Carex crebriflora*
Wood Sedge	*Carex digitalis*
Hummock Sedge	*Carex joorii*
Reflexed Sedge	*Carex retroflexa*

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Common Name	Scientific Name
Furrowed Sedge	*Carex striatula*
False Nutgrass	*Cyperus strigosus*
Little-head Nutrush	*Scleria oligantha*
Dioscoreaceae (Yam Family)	
Wild Yam	*Dioscorea quaternata*
Ebenaceae (Persimmon Family)	
Common Persimmon	*Diospyros virginiana*
Ericaceae (Heath Family)	
One-Flower Indian Pipe	*Monotropa uniflora*
Largecluster Blueberry	*Vaccinium amoenum*
Farkleberry	*Vaccinium arboreum*
Euphorbiaceae (Spurge Family)	
Virginia Three-seeded Mercury	*Acalypha virginica*
Eyebane Chamaesyce	*Chamaesyce nutans*
Bull Nettle	*Cnidoscolus texanus*
Woolly Croton	*Croton capitatus*
Northern Croton	*Croton glandulosus*
Flowering Spurge	*Euphorbia corollata*
Fabaceae (Legume Family)	
Mimosa Tree	*Albizia julibrissin*
Hog Peanut	*Amphicarpaea bracteata*
Redbud	*Cercis canadensis*
Partridge Pea	*Chamaecrista fasciculata*
Pigeon Wings	*Clitoria mariana*
Fernald's Beggar's Ticks	*Desmodium fernaldii*
Maryland Beggar's Ticks	*Desmodium marilandicum*
Barestem Beggar's Ticks	*Desmodium nudiflorum*
Panicled Beggar's Ticks	*Desmodium paniculatum*
Fewflowered Beggar's Ticks	*Desmodium pauciflorum*
Pineland Beggar's Ticks	*Desmodium strictum*
Coral Bean	*Erythrina herbacea*
Honey Locust	*Gleditsia triacanthos*
Round-head Bush Clover	*Lespedeza capitata*
Japanese Bush Clover	*Lespedeza striata*
Slender Bush Clover	*Lespedeza virginica*
Powderpuff	*Mimosa strigillosa*
Broadleaf Snoutbean	*Rhynchosia latifolia*
Black Locust	*Robinia pseudoacacia*
Sensitive Brier	*Schrankia nuttallii*
Bagpod	*Sesbania vesicaria*
Fuzzy Bean	*Strophostyles umbellata*
Pencil Flower	*Stylosanthes biflora*
Pale Vetch	*Vicia caroliniana*
Kentucky Wisteria	*Wisteria macrostachya*
Fagaceae (Beech Family)	
Trailing Chinkapin	*Castanea alnifolia*
White Oak	*Quercus alba*
Southern Red Oak	*Quercus falcata*
Overcup Oak	*Quercus lyrata*
Blackjack Oak	*Quercus marilandica*
Water Oak	*Quercus nigra*
Willow Oak	*Quercus phellos*

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Common Name	Scientific Name
Shumard Red Oak	*Quercus shumardii*
Post Oak	*Quercus stellata*
Gentianaceae (Gentian Family)	
Prairie Rose Gentian	*Sabatia campestris*
Geraniaceae (Geranium Family)	
Carolina Gernaium	*Geranium carolinianum*
Hammamelidaceae (Witch Hazel Family)	
Sweetgum	*Liquidamber styraciflua*
Hippocastanaceae (Buckeye Family)	
Red Buckeye	*Aesculus pavia*
Hypericaceae (St. Johnswort Family)	
St. Andrew's Cross	*Hypercium hypericoides*
Iridaceae (Iris Family)	
Purple Pleatleaf	*Alophia drummondii*
Juglandaceae (Walnut Family)	
Water Hickory	*Carya aquatica*
Bitternut Hickory	*Carya cordiformis*
Shellbark Hickory	*Carya laciniosa*
Black Hickory	*Carya texana*
Mockernut Hickory	*Carya tomentosa*
Black Walnut	*Juglans nigra*
Juncaceae (Rush Family)	
Forked Rush	*Juncus dichotomus*
Border Rush	*Juncus marginatus*
Lamiaceae (Mint Family)	
Water Horehound	*Lycopus rubellus*
Beefsteak Plant	*Perilla frutescens*
Common Selfheal	*Prunella vulgaris*
White-bracted Mountain Mint	*Pycnanthemum albescens*
Narrowleaf Mountain Mint	*Pycnanthemum tenuifolium*
Lyreleaf Sage	*Salvia lyrata*
American Germander	*Teucrium canadense*
Lauraceae (Laurel Family)	
Sassafras	*Sassafras albidum*
Liliaceae (Lily Family)	
White Trout Lily	*Erythronium albidium*
Great Solomon's Seal	*Polygonatum biflorum*
Linaceae (Flax Family)	
Sucker Flax	*Linum medium*
Malvaceae (Mallow Family)	
Woods Poppy Mallow	*Callirhoe papaver*
Swamp Rose Mallow	*Hibiscus moscheutus*
Melastomataceae (Melastoma Family)	
Maryland Meadow Beauty	*Rhexia mariana*

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Common Name	Scientific Name
Menispermaceae (Moonseed Family)	
Carolina Snailseed	*Cocculus carolinus*
Moraceae (Mulberry Family)	
Osage Orange	*Maclura pomifera*
Red Mulberry	*Morus rubra*
Myricaceae (Waxmyrtle Family)	
Southern Waxmyrtle	*Myrica cerifera*
Nymphaeaceae (Waterlily Family)	
Spatterdock	*Nuphar lutea*
Oleaceae (Olive Family)	
Fringe Tree	*Chionanthus virginica*
Swamp Privet	*Forestiera acuminata*
White Ash	*Fraxinus americana*
Green Ash	*Fraxinus pennsylvanica*
Chinese Privet	*Ligustrum sinense*
Onagraceae (Evening Primrose Family)	
Tall Gaura	*Gaura longiflora*
Winged Seedbox	*Ludwigia decurrens*
Showy Evening Primrose	*Oenothera speciosa*
Orchidaceae (Orchid Family)	
Yellow Lady Slipper	*Cypripedium kentuckiense*
Southern Twayblade	*Listeria australis*
Oneleaf Adder's Mouth	*Malaxis unifolia*
Oxalidaceae (Wood Sorrell Family)	
Yellow Wood Sorrell	*Oxalis dillenii*
Golden Wood Sorrell	*Oxalis priceae*
Passifloraceae (Passion Flower Family)	
Maypop Passion Flower	*Passiflora incarnata*
Yellow Passion Flower	*Passiflora lutea*
Phytolaccaceae (Poke Weed Family)	
Common Pokeweed	*Phytolacca americana*
Platanaceae (Sycamore Family)	
Sycamore	*Platanus occidentalis*
Poaceae (Grass Family)	
Big Bluestem	*Andropogon gerardii*
Bushy Bluestem	*Andropogon glomeratus*
Splitbeard Bluestem	*Andropogon ternarius*
Broomsedge Bluestem	*Andropogon virginicus*
Giant Cane	*Arundinaria gigantea*
Broadleaf Chasmanthium	*Chasmanthium latifolium*
Spike Chasmanthium	*Chasmanthium laxum*
Chasmanthium	*Chasmanthium sessiliflorum*
Forked Dichanthelium	*Dichanthelium dichotomum*
Dichanthellium	*Dichanthelium sphaerocarpon*
Kleberg Bluestem	*Dichanthelium annulatum*

Common Name	Scientific Name
Barnyard Grass	*Echinochloa walteri*
Virginia Wildrye	*Elymus virginicus*
Bigtop Lovegrass	*Eragrostis hirsuta*
Sugarcane Plumgrass	*Erianthus giganteus*
Narrow Plumgrass	*Erianthus strictus*
Catchfly Grass	*Leersia lenticularis*
Rice Cutgrass	*Leersia oryzoides*
White Grass	*Leersia virginica*
Perennial Ryegrass	*Lolium perenne*
Twoflower Melic	*Melica mutica*
Basketgrass	*Oplismenus hirtellus*
Beaked Panicum	*Panicum anceps*
Warty Panicum	*Panicum verruccosum*
Florida Paspalum	*Paspalum floridanum*
Thin Paspalum	*Paspalum setaceum*
Woodland Bluegrass	*Poa sylvestris*
Slender Indiangrass	*Sorghastrum elliottii*
Yellow Indiangrass	*Sorghastrum nutans*
Purpletop	*Tridens flavus*
Longspike Tridens	*Tridens strictus*
Polemoniaceae (Phlox Family)	
Downy Phlox	*Phlox pilosa*
Polygonaceae (Milkwort Family)	
Buckwheat Vine	*Brunnichia ovata*
Dotted Smartweed	*Polygonum punctatum*
Ranunculaceae (Buttercup Family)	
Purple Meadowrue	*Thalictrum dasycarpum*
Rhamnaceae (Buchtorn Family)	
Carolina Buckthorn	*Rhamnus caroliniana*
Rosaceae (Rose Family)	
Pear Buckthorn	*Crataegus calpodendron*
Parsley Hawthorn	*Crataegus marshallii*
Western Mayhaw	*Crataegus opaca*
Sabine Hawthorn	*Crataegus sabineana*
Pasture Haw	*Crataegus spathulata*
Indian Strawberry	*Duchesnia indica*
White Avens	*Geum canadense*
Sulphur Cinquefoil	*Potentilla recta*
Mexican Plum	*Prunus mexicana*
Black Cherry	*Prunus serotina*
Flatwood Plum	*Prunus umbellata*
Blackberry	*Rubus* sp.
Southern Dewberry	*Rubus trivialis*
Rubiaceae (Madder Family)	
Common Buttonbush	*Cephalanthus occidentalis*
Rough Buttonweed	*Diodia teres*
Virginia Buttonweed	*Diodia virginiana*
Catchweed Bedstraw	*Galium aparine*
Woods Bedstraw	*Galium circaezans*
Partridge Berry	*Mitchella repens*

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Common Name	Scientific Name
Salicaaceae (Willow Family)	
Black Willow	*Salix nigra*
Sapindaceae (Soapberry Family)	
Alabama Supplejack	*Berchemia scandens*
Sapotaceae (Sapodilla Family)	
Wollybucket Bumelia	*Bumelia lanuginosa*
Saururaceae (Lizard's Tail Family)	
Lizard's Tail	*Saururus cemuus*
Scrophulariaceae (Figwort Family)	
Beach Agalinis	*Agalinus fasciculata*
Old Field Toadflax	*Linaria canadensis*
Sharpwing Monkey Flower	*Mimulus alatus*
Loose Penstemon	*Penstemon australis*
Common Speedwell	*Veronica arvensis*
Smilacaceae (Greenbriar Family)	
Saw Greenbriar	*Smilax bona-nox*
Cat Greenbriar	*Smilax glauca*
Laurel Greenbriar	*Smilax laurifolia*
Common Greenbriar	*Smilax rotundifolia*
Styracaceae (Styrax Family)	
Snowdrop Tree	*Halesia diptera*
Silver Bells	*Styrax americana*
Tiliaceae (Linden Family)	
American Basswood	*Tilia americana*
Ulmaceae (Elm Family)	
Texas Sugarberry	*Celtis laevigata*
Netleaf Hackberry	*Celtis reticulata*
Water Elm	*Planaera aquatica*
Winged Elm	*Ulmus alata*
American Elm	*Ulmus americana*
Slippery Elm	*Ulmus rubra*
Urticaceae (Nettle Family)	
False Nettle	*Boehmeria cylindrica*
Valerianaceae (Valerian Family)	
Beaked Comsalad	*Valerianella radiata*
Verbenaceae (Verbena Family)	
American Beautyberry	*Callicarpa americana*
Lopseed	*Phryma leptostachya*
Texas Verbena	*Verbena officinale*
Violaceae (Violet Family)	
Prairie Violet	*Viola pratincola*
Hairy Violet	*Viola villosa*

Common Name	Scientific Name
Vitaceae (Grape Family)	
Peppervine	*Ampelopsis arborea*
Virginia Creeper	*Parthenocissus quinquefolia*
Summer Grape	*Vitis aestivalis*
Sweet Winter Grape	*Vitis cinerea*
Post Oak Grape	*Vitis lincecumii*
Catbird Grape	*Vitis palmata*
Riverbank Grape	*Vitis rotundifolia*

APPENDIX 10
AQUATIC VEGETATION OF CADDO LAKE

The following aquatic vascular plants were identified by personnel of the Texas Parks and Wildlife Department during lake surveys in September 1980 and 1993 (Darville and Brock 1993b). Sampling methods included a visual inspection of the aquatic vegetation and identification of the plants using a key by Fassett (1972). For the two collection periods a total of 42 species were found with 36 being found in the 1980 collection and 22 in the 1993 collection. The 1993 report estimated that 95% of the lake is covered with some form of aquatic vegetation.

Common Name	Scientific Name
American Lotus	*Nelumbo lutea*
Arrowhead	*Sagittaria papillosa*
Baldcypress	*Taxodium distichum*
Black Willow	*Salix nigra*
Bladderwort	*Utricularia sp.*
Blue-green Algae	Cyanophyta
Brazilian Elodea	*Egeria densa*
Bull Tongue	*Sagittaria falcata*
Bulrush	*Scirpus sp.*
Buttonbush	*Cephalanthus occidentalis*
Catttail	*Typha sp.*
Cutgrass	*Zizaniopsis milacea*
Coontail	*Ceratophyllum demeraum*
Duckweed	*Lemna sp.*
Duckpotato	*Sagittaria latifolia*
False Loosestrife	*Ludwigia leptocarpa*
Fanwort	*Cabomba caroliniana*
Filamentous Algae	Chlorophyta
Floating Waterprimrose	*Ludwigia peploides*
Frogbit	*Limnobium spongia*
Giant Duckweed	*Spirodela polyrhiza*
Hydrilla	*Hydrilla verticillata*
Lizard's Tail	*Saururus sp.*
Maidencane	*Panicum hemitomon*
Muskgrass	*Chara sp.*
Parrotfeather	*Myriophyllum brasiliense*
Pennywort	*Hydrocotyle sp.*
Pondweed	*Potamogeton sp.*
Rush	*Juncus sp.*
Smartweed	*Polygonum sp.*
Spikerush	*Eleocharis sp.*
Umbrella Sedge	*Cyperus spp.*
Water Fern	*Azolla spp.*

Common Name	Scientific Name
Water Hyacinth	*Eichornia crassipes*
Waterleaf	*Hydrolea sp.*
Waterlocust	*Gleditsia aquatica*
Watermeal	*Wolffia sp.*
Watershield	*Brasenia schreberi*
Waterweed	*Elodea sp.*
White Waterlily	*Nymphaea odorata*
Wild Celery	*Vallisneria americana*
Yellow Waterlily	*Nuphar luteum*

APPENDIX B

SOIL-TO-EARTHWORM BIOACCUMULATION FACTORS FOR ECOLOGICAL ASSESSMENT

020202

Earthworm Bioaccumulation Factors (BAFs)

Chemical	Bioaccumulation Factor [a]	Reference
Organics		
Acetone	NA	---
Benzoic Acid	NA	---
Bis(2-ethylhexyl)phthalate	NA	---
2-Butanone	NA	---
Methylene chloride	NA	---
PAHs		
Acenaphthene	3.00E-01	Beyer and Stafford, 1993
Acenaphthylene	2.20E-01	Beyer and Stafford, 1993
Anthracene	3.20E-01	Beyer and Stafford, 1993
Benzo(a)anthracene	2.70E-01	Beyer and Stafford, 1993
Benzo(a)pyrene	3.40E-01	Beyer and Stafford, 1993
Benzo(b)fluoranthene	2.10E-01	Beyer and Stafford, 1993
Benzo(g,h,i)perylene	1.50E-01	Beyer and Stafford, 1993
Benzo(k)fluoranthene	2.10E-01	Beyer and Stafford, 1993
Chrysene	4.40E-01	Beyer and Stafford, 1993
Dibenzo(a,h)anthracene	4.90E-01	Beyer and Stafford, 1993
Fluoranthene	3.70E-01	Beyer and Stafford, 1993
Fluorene	2.00E-01	Beyer and Stafford, 1993
Indeno(1,2,3-CD)pyrene	4.10E-01	Beyer and Stafford, 1993
Phenanthrene	2.80E-01	Beyer and Stafford, 1993
Pyrene	3.90E-01	Beyer and Stafford, 1993
Toluene	NA	---
Xylenes	NA	---
Inorganics		
Antimony	NA	---
Arsenic	4.80E-02	Beyer and Cromartie, 1987
Barium	3.60E-01	Beyer and Stafford, 1993
Cadmium	4.60E+00	Beyer and Stafford, 1993
Chromium	7.70E-01	Beyer and Cromartie, 1987
Lead	5.30E-01	Beyer and Cromartie, 1987
Mercury (mercuric acetate)	3.65E-01	Kabata-Pendias and Pendias, 1984
Nickel	1.80E+00	Kabata-Pendias and Pendias, 1984
Selenium	NA	---
Silver	NA	---
Thallium	NA	---

[a] Expressed in dry weight (to convert to wet weight divide by 4 – assumes earthworms are 75% moisture)
NA – Not available

APPENDIX C

REFERENCE TOXICITY VALUES FOR ECOLOGICAL ASSESSMENT

Chemical	Species	Duration of Exposure	Acute/Chronic	Dose (mg/kg-BW)	Effect	Reference	Comments
Organics							
Acetone	rat	13 weeks	chronic NOAEL	900	no effects on spermatogenesis	Deitz et al. 1991	5+control,3rd highest
Benzoic Acid	rat	4 generations	chronic no effects dose	500	no change protein effic., lit size, or histol.	Kleckebusch and Lang, 1960 as	cited in Informatics, 1972.
Bis(2-ethylhexyl)phthalate	mouse	17 days gestation	acute NOAEL	65	no offspring effects	Tyl et al 1988	4+contr,2nd lowest
2-Butanone	rat	generational	chronic NOAEL	1771	no effect on pup survival	IRIS (Cox et al 1975)	orig ref not reviewed/RfD
Methylene chloride	Mouse	104 weeks	chronic NOAEL	185	non-neoplastic histopathological effects	Serota et. al., 1986b.	4+control; DW study
PAHs							
Acenaphthene	ND	ND	ND	ND	ND	ND	gavage only
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND
Anthracene	rat	550	chronic no effect dose	15	no effects on lifespan or histology	IRIS, 1994	original paper not reviewed (in German)
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	mouse	generational	chronic no effect dose	130	no effect on repro/fertility	Rigdon et al 1965	3+cont,highest dose
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	gavage only
Indeno(1,2,3-CD)pyrene	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND
Toluene	mouse	4 weeks	chronic NOAEL	22	no effect on immuno function	Hsieh et al 1989	3+contr,2nd lowest
Xylenes	ND	ND	ND	ND	ND	ND	gavage studies only
Inorganics							
Antimony	rats	lifetime	chronic NOAEL	0.14	reduced survival	Schroeder et al. 1970	1 conc+control; DW study
Arsenic	rat	2 years	chronic NOAEL	3.63	no dec survival or bw	Byron et al 1967	5+contr, 2nd highest
Barium	mouse	92 days	chronic NOAEL	182.9	no sign mort. or behavior effects	Dietz et al 1992	5+control,2nd highest
Cadmium	rat	24 weeks	chronic NOAEL	1.64	no effects on motor or kidney	Kotsonis and Klaassen 1978	
Chromium III	mouse	35 days	chronic effect dose	4.57	dec spermatogenesis	Zahid et al 1990	3(lowest)+control
Chromium VI	mouse	35 days	chronic effect dose	2.3	dec spermatogenesis	Zahid et al 1990	3(lowest)+cont
Lead	rat	12-15 wks?	chronic NOAEL	4.6	no depress immunity	Luster et al. 1978	two conc used+contr
Mercury (mercuric acetate)	Rat	52 weeks	chronic NOAEL	31.5	kidney enlargement	Fitzhugh et. al., 1950	5+control
Nickel	rat	3 generation	chronic effect dose	12.5	inc. # stillborns (1st gen. only)	Ambrose et al 1976	3(lowest) +control
Selenium	mouse	30 d pre,18 d gest	chronic NOAEL	0.375	no effects on fetal growth	Nobunaga et al 1979	2+control;lowest
Silver	rats	~12 weeks	chronic no effects dose	20	no effects	Walker, 1971.	3
Thallium	rat	15 weeks	chronic NOAEL	0.6	no sign inc mortality	Downs et al 1960	4+control,3rd lowest

Comments:
(lowest) or (highest) indicates that the dose represents the lowest or highest concentration tested in study
ND - No data available
bw bodyweight

020204

Chemical	Species	Duration of Exposure	Acute/Chronic	Dose (mg/kg--BW)	Effect	Reference	Comments
Organics							
Acetone	Japanese Quail	8 days (5 d treat, 3 obs)	acute no effect dose	14132	no overt signs of toxicity	Hill and Camardese, 1986.	3+control
Benzoic Acid	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	White Leghorns	4 weeks	chronic effects dose	564	dec bw, dec in egg production, cholesterol changes	Wood and Bitman, 1980.	1+control
2-Butanone	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND
PAHs							
Acenaphthene	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluornathene	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND
Fluornathene	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-CD)pyrene	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND
Xylenes	J. Quail (14 days)	5 days treated, 3 untreated	acute NOAEL	1943	no overt signs of toxicity	Hill and Camardese, 1986.	3+control
Inorganics							
Antimony	ND	ND	ND	ND	ND	ND	ND
Arsenic	1 dayold mallard	9 weeks	chronic NOAEL	28.9	no sign behavioral effects	Whitworth et al 1991	3+control,2nd lowest
Barium	ND	ND	ND	ND	ND	ND	ND
Cadmium	mallard	90 days	chronic LOAEL	20.03	egg production suppression	White and Finley 1978	3+control;highest
Chromium III	chicks (3 weeks)	4 weeks	chronic NOAEL	95.2	no effects on body wt or mortality	Hill and Matrone, 1970.	3+control
Chromium VI	3 week chicks	4 weeks	chronic NOAEL	95	no effect on body wt	Hill and Matrone 1970	3+contr, 2nd highest
Lead	J quail chicks	5 weeks	chronic NOAEL	26	no anemia,no depressed growth	Morgan et al 1975	4+control,2nd lowest
Mercury	J quail <1 year	20 weeks to 1 yr	chronic NOAEL	0.179	no effects	Hill and Shaffner 1976	5+control,lowest
Nickel	1 dayold chick	4 weeks	chronic NOAEL	16.9	no depressed weight gain	Weber and Reid 1968	6+control,2nd lowest
Selenium	mallards	pre to after eggs laid	chronic NOAEL	0.49	no effects	Heinz et al 1989	5+control,third lowest
Silver	Chicks (1 day old)	28 days	chronic effect dose	86	increased mortality, depressed growth	Peterson and Jensen 1975	1+control
Thallium	pheasant	single dose	acute LD50	19.2	mortality	Hudson et al 1984	single acute dose

ND - No data available

020205